International

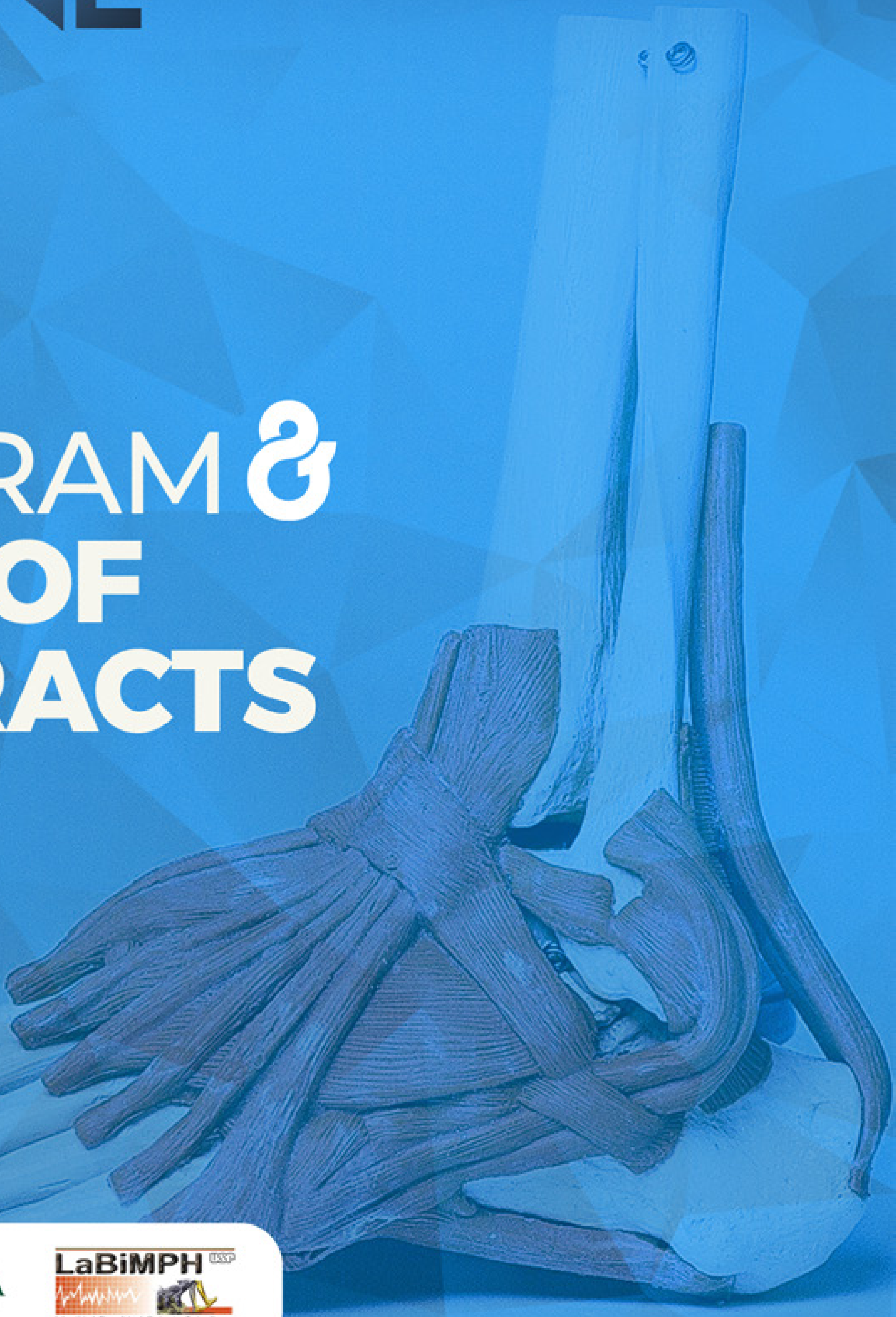
FOOT & ANKLE

Biomechanics Meeting 2021

ONLINE

APRIL 11 TO 14, 2021

Everywhere • Anywhere



FINAL PROGRAM & BOOK OF ABSTRACTS

SBB
BRAZILIAN SOCIETY OF BIOMECHANICS

MEDICINA USP

LaBiMPH USP
Laboratório de Biomecânica do Movimento e Postura Humana

Final Program & Book of Abstracts

i-FAB 2021 - International Foot & Ankle Biomechanics Meeting

April 11 to 14, 2021 - Virtual Meeting

COORDINATOR

Isabel C. N. Sacco

University of Sao Paulo, Sao Paulo – Brazil

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WELCOME MESSAGE

Isabel Sacco
Chair of i-FAB 2021
University of Sao Paulo – School of Medicine

As the host of the next i-FAB 2021 in Brazil, it is my pleasure to announce and invite you to join us in this unique scientific venture in the next International Foot and Ankle Biomechanics Virtual Meeting, organized by the i-FAB Committee and the University of São Paulo – USP.

The event will take place from April 11 to 14, 2021 and it will happen for the first time virtually.

This is a great opportunity to discuss the cutting edge research on foot and ankle biomechanics from anywhere in the world.

i-FAB 2021 will be a four-day scientific program with an exciting agenda. The program will be multidisciplinary and full of presentations from our international guests and invited speakers. We are planning pre-congress courses and workshops, 5 international lectures, 18 oral sessions, 2 special sessions and poster session on demand, as well as moments of fraternization and exchange of experience between professionals from different parts of the world.

The focus of the presentations will be subjects related to Chronic Ankle Instability, Clinical Biomechanics, Diabetic foot, Foot Biomechanics, Foot-Ankle Modelling, Footwear/Orthotics, Kinematics Methodological Aspects, Orthopedics, Pediatrics, Running, Sports, Tissue Biomechanics and Weight Bearing CT. All professionals and students who are directly or indirectly involved in the topics are welcome to participate to contribute to the depth of discussions during the event.

We will promote a multidisciplinary event that integrates different complementary areas in order to understand the Foot and Ankle in all its dimensions – FABMAN – Foot and Ankle Biomechanics Multidisciplinary ActioN!

The main objective of the International Foot and Ankle Biomechanics Meeting is to promote interactions between people interested in foot and ankle biomechanics, and to connect areas that may not traditionally have a strong biomechanical component.

In particular, i-FAB 2021 aims to (i) provide up-to-date knowledge about foot and ankle biomechanics, rehabilitation and orthopedics of these segments; (ii) expand the research community in Foot and Ankle by connecting people from different countries working in universities, clinics and industries; (iii) facilitate debate on key issues for this community; (iv) and foster ongoing activities among researchers and research users.

We welcome all participants with an interest in foot and ankle biomechanics, orthopedics and rehabilitation, including academics, physicians, podiatrists, surgeons, engineers, physical education professionals, physical therapists and other health professionals, as well as related professionals, to the footwear industry, manufacturing of insoles / orthoses and surgical equipment.

This is a great opportunity to develop a truly multidisciplinary approach to addressing the challenges that experimental and computational foot and ankle biomechanics represent – FABMAN – Foot and Ankle Biomechanics Multidisciplinary ActioN!

ORGANIZING COMMITTEE

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Isabel Sacco (School of Medicine, University of Sao Paulo, Brazil)

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Howard Hillstrom (Motion Analysis Laboratory, New York City – United States)
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Sicco Bus (University of Amsterdam, Amsterdam – Netherlands)
William R. Ledoux (CLiMB, VA Center for Limb Loss and MoBility – Washington, United States)

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Fabio Serrao (Federal University of São Carlos, São Paulo – Brazil)
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William R. Ledoux (CLiMB, VA Center for Limb Loss and MoBility – Washington, United States)
Wouter Schallig (AMC and VUmc, Amsterdam – Netherlands)
Zimi Sawacha (University of Padova – Italy)

GENERAL **INFORMATION**

EVENT DATE AND TIME

April 11 to 14, 2021
10am-5:15pm | São Paulo, Brazil (GMT-3)

All program times are presented on Brazilian Time (GMT-3).
Be sure to consult it before planning your activities' agenda.

To help you use the global converter at: https://bit.ly/3ryCrio

Watch out for Daylight Saving Time at your region.

OFFICIAL LANGUAGE

The conference official language is English, and all slides and posters must be presented in English.

Simultaneous translation from English to Portuguese will be available during all conference.

ON DEMAND

All conference content will be available on demand for 90 days after the event at the official platform.

FABPARTY

In order to get together and enjoy a smooth relaxing time with our biomechanics colleagues, we will be throwing the FABPARTY on April 13th, right after the last session of the day from 5:15pm.

It will be an opportunity to network, chat and share science at a nice online environment!

We count on your PARTICIPATION!

CERTIFICATE

The participation and presentation certificates will be available to download at the conference website using your login information by April 15th.

REGISTRATION **FEES**

MEMBERS

SBB and ABTPé	R$ 180,00

NON MEMBERS

Non-Brazilians	$ 100,00
Brazilians	R$ 200,00

EDC MEMBERS

Non-Brazilians	$ 35,00

UNDERGRADUATE

Non-Brazilians	$ 50,00
Brazilians	R$ 100,00

GRADUATE

Non-Brazilians	$ 100,00
Brazilians	R$ 200,00

*Member Societies: Affiliate member with payment of current membership dues: Brazilian Society of Biomechanics (SBB) and Brazilian Association of Ankle and Foot Medicine and Surgery (ABTPé) affiliates
** EDC – Economically Developing Countries

IMPORTANT:

The registration cost of the virtual meeting was substantially reduced. Our registration fee is based on a goal of breaking even on meeting-related costs. It will allow us to cover all costs of this new format and keep an excellent scientific programing.
Registration fees will be charged in Reais (BRL).
Amounts quoted in US dollars (USD) are for approximate reference only.
The actual amount charged to your credit card will depend on the currency conversion rate in your home country and the rates of the credit card company uswed.
The exchange rate fluctuates between 5.00 to 6.00 BRL for each dollar and 6.00 to 7.00 BRL for each euro.

Participants registration fees includes:

- SHORT COURSE: Gait Retraining for Running Injuries: Focus on the Foot, by Irene Davis *registration required (free of charge)*
- MCG Symposium: Symposium of the ISB Technical Group in Motor Control *registration required (free of charge)*
- Opening ceremony
- Access to scientific sessions and exhibition
- Chat with the sponsors
- Networking meetings

SPONSORS

SPONSOR – SILVER QUOTA

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SUPPORT

EXHIBITORS

PROMOTER

INSTITUCIONAL SUPPORT

ORGANIZATION

ONLINE **PLATAFORM**

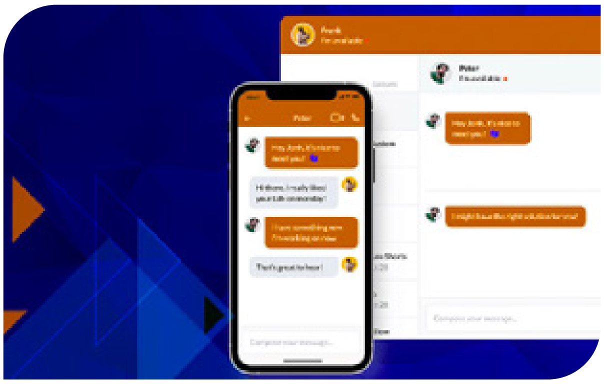
Acess here:

ifab2021.neopix.online

ON DEMAND LEARNING

Get access to 25+ hours of the lastest studies on Foot & Ankle Biomechanics from the community around the world. Watch and interact with the speakers LIVE or just make your agenda and watch the classes when and where you want to.

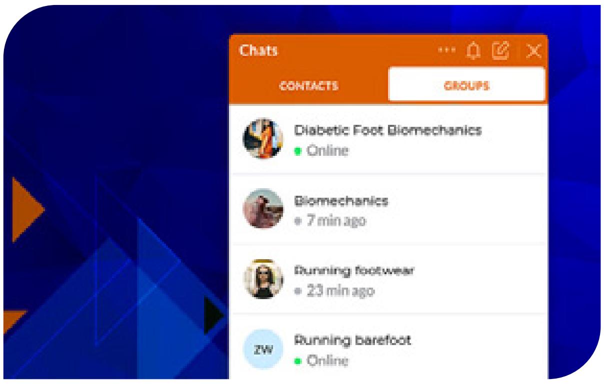
Every class will be available ON DEMAND online 90 days after the event (if the speaker has granted permission).



NETWORKING

Through a modern and user friendly online platform, the attendees of the i-FAB 2021 will be able to interact, debate about the sessions, chat with authors and exchange experiences.

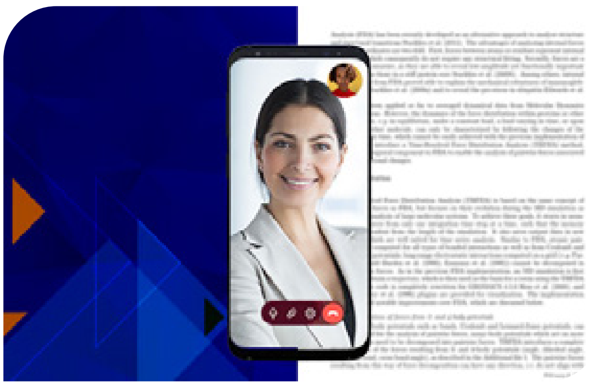
Meet your favorite speaker in the networking area for more details or have private voice and video meeting with others participants.



ONLINE FORUM

During the i-FAB 2021 Online, attendees will be able to start one-on-one conversations and connect in groups in thematics rooms. Want to talk about diabetic foot or the collapsing foot? No problem, just creat a group and invite people to join you!

This will be an opportunity to chat in real time with colleagues from around the world on the most current topics or those you like most.



E-POSTERS SESSIONS

The technical papers will be presented in poster format in a very interactive way.

Participants will be able to check out the papers and it will be possible to chat in real time with the authors, either by text, video call or audio, to learn more or answer questions.

APRIL 11, 2021
10:00am - 5:15pm

ROOM 1

Time	Session
10:00am 12:30pm	**MCG Symposium** **Symposium of the ISB Technical Group in Motor Control**
12:30pm 1:00pm	BREAK
1:00pm 1:20pm	**OPENING CEREMONY**
1:20pm 2:05pm	**ORAL SESSION 1** **Weight Bearing CT I** Chairs: Annamaria Guiotto and Jayishni Maharaj
2:10pm 2:30pm	**SPONSOR TIME LECTURE** Apamed/Vicon
2:30pm 3:15pm	**ORAL SESSION 2** **Chronic Ankle Instability** Chairs: Sandra Aliberti and Eneida Yuri Suda
3:15pm 3:25pm	BREAK
3:25pm 3:45pm	**SPONSOR TIME LECTURE** AMTI
3:45pm 5:15pm	**SHORT COURSE** **Gait Retraining for Running Injuries: Focus on the Foot** Irene Davis

POSTER SESSION

APRIL 12, 2021
10:00am - 5:20pm

ROOM 1

Time	Session
10:00am 10:10am	**OPENING**
10:10am 10:50am	**KEYNOTE SESSION 1** **What's happening in my Achilles tendon? The effects of running in different footwear** Keynote speaker: Toni Arndt Chair: Isabel Sacco
10:55am 11:50am	**ORAL SESSION 3** **Weight Bearing CT II** Chairs: Rajshree Hillstrom and Sophie de Mits
11:50am 12:20pm	BREAK
12:20pm 12:25pm	**SPONSOR TIME DEMO** Dass
12:25pm 12:30pm	**SPONSOR TIME DEMO** Carci
12:30pm 1:10pm	**KEYNOTE SESSION 2** **Biomechanics, physics, and evolution of foot arches** Keynote speaker: Madhusudhan Venkadesan Chair: William Ledoux
1:15pm 2:20pm	**ORAL SESSION 5** **Foot Biomechanics** Chairs: Julie Stebbins and Deyse Borges Machado
2:20pm 2:30pm	BREAK
2:30pm 2:40pm	**SPONSOR TIME DEMO** Ebersmed
2:40pm 4:30pm	**SPECIAL SESSION 1** **Diabetic Foot Biomechanics** Chairs: David G. Armstrong and Sicco Bus
4:35pm 5:20pm	**ORAL SESSION 7** **Kinematics Methodological Aspects I** Chairs: Karine Jacon Sarro and Alessandra Bento Matias

ROOM 2

Time	Session
10:55am 11:40pm	**ORAL SESSION 4** **Diabetic foot I** Chairs: Mary K. Hastings and Anne Rasmussen
1:15pm 2:10pm	**ORAL SESSION 6** **Tissue Biomechanics** Chairs: Claire Brockett and Heiliane de Brito Fontana
4:35pm 5:20pm	**ORAL SESSION 8** **Sports** Chairs: Andresa Germano and Liu Chiao Yi

POSTER SESSION

APRIL 13, 2021
10:00am - 6:30pm

ROOM 1

Time	Session
10:00am 10:10am	**OPENING**
10:10am 10:50am	**KEYNOTE SESSION 3** **Investigation of Human Foot Function Using Approaches in Imaging and Musculoskeletal Modeling** Keynote speaker: Michael Rainbow Chair: Howard Hillstrom
10:50am 11:10am	**SPONSOR TIME LECTURE** Novel
11:15am 12:20pm	**ORAL SESSION 9** **Foot-Ankle Modelling** Chairs: Zimi Sawacha and Fabiola Spolaor
12:20pm 12:50pm	BREAK
12:50pm 1:00pm	**SPONSOR TIME DEMO** X Sensor
1:00pm 2:15pm	**ORAL SESSION 11** **Footwear/ Orthotics** Chairs: Sharon Dixon and Carina Price
2:20pm 2:30pm	BREAK
2:30pm 2:40pm	**SPONSOR TIME DEMO** HS Technology
2:40pm 3:35pm	**ORAL SESSION 13** **Diabetic foot II** Chairs: Claudia Giacomozzi and Érica Queiroz da Silva
3:40pm 3:50pm	BREAK
3:50pm 4:00pm	**SPONSOR TIME DEMO** Qualisys
4:00pm 5:05pm	**ORAL SESSION 15** **Clinical Biomechanics I** Chairs: Rosemary Dubbeldam and Lena Fennen
5:15pm	**FABParty**

ROOM 2

Time	Session
11:15am 12:20pm	**ORAL SESSION 10** **Orthopedics I (surgical aspects)** Chairs: Elizabeth Pedersen and Ana Paula Simões
1:00pm 2:15pm	**ORAL SESSION 12** **Pediatrics** Chairs: Kirsten Tulchin Francis and Cylie Williams
2:40pm 3:35pm	**ORAL SESSION 14** **Kinematics Methodological Aspects II** Chairs: Elyse Passmore and Amy L. Lenz
4:00 4:45pm	**ORAL SESSION 16** **Orthopedics II** Chairs: Ruth L. Chimenti and Isabelle Van Dalen

POSTER SESSION

APRIL 14, 2021
10:00am - 5:10pm

ROOM 1

Time	Session
10:00am 10:10am	**OPENING**
10:10am 10:50am	**KEYNOTE SESSION 4** **The Collapsing Foot: Challenges in Diagnosis & Treatment & The Role of the Weight-Bearing CT** Keynote speaker: Cesar de Cesar Netto Chair: Paolo Caravaggi
10:55am 12:45pm	**SPECIAL SESSION 2** **Weight-Bearing CT** Chairs: Alberto Leardini and Francois Lintz
12:45pm 1:15pm	BREAK
1:15pm 1:20pm	**SPONSOR TIME DEMO** Delsys
1:20pm 2:35pm	**ORAL SESSION 17** **Running** Chairs: Irene Davis and Sarah Ridge
2:40pm 2:45pm	BREAK
2:45pm 3:05pm	**SPONSOR TIME LECTURE** Curve Beam
3:05pm 4:00pm	**ORAL SESSION 18** **Clinical Biomechanics II** Chairs: Thanaporn Tunprasert and Aoife Healy
4:05pm 4:45pm	**KEYNOTE SESSION 5** **The Foot Core Paradigm: Let's Think Differently about the Foot** Keynote speaker: Irene Davis Chair: Sicco Bus
4:50pm 5:10pm	**CLOSING CEREMONY**

POSTER SESSION

PROGRAM
SUNDAY, APRIL 11, 2021

10:00am - 12:30pm
(GMT-3)

Room 1

Simultaneous translation available (EN-PT)

MCG Symposium

Symposium of the ISB Technical Group in Motor Control

Model-based comparative biomechanics and muscle function analysis of simulated crouch gait by healthy children and crouch gait in CP children
Antonio Veloso, University of Lisbon (Portugal)

Motor control alterations in diabetic neuropathy: insights for rehabilitation strategies
Eneida Yuri Suda, Universidade de São Paulo (Brazil)

Motor control at the ankle joint: neuromuscular adaptations to training and injury
Marco Vaz, Universidade Federal do Rio Grande do Sul (Brazil)

Biomechanics and motor control of challenged gait in older adults
Eliane Celina Guadagnin, Universidade Federal do Pampa (Brazil)

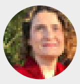
The midfoot passive mechanical properties affect the lower limb biomechanics in weight-bearing activities
Fabrício Magalhães, Federal University of Minas Gerais (Brazil)

12:30 - 1:00pm
(GMT-3)

Break

1:00 - 1:20pm
(GMT-3)

Opening Ceremony



Isabel Sacco
Universidade de São Paulo; President of i-FAB 2021

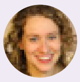
1:20 - 2:05pm
(GMT-3)

Room 1

Simultaneous translation available (EN-PT)

ORAL SESSION 1

Weight Bearing CT I



Chair: Annamaria Guiotto
University of Padua

Chair: Jayishni Maharaj
Griffith University

1:20-1:27pm	**3D Weight-Bearing Bone Architecture Measures to Enhance Plantar Loading Analysis in the Diabetic Foot** *Claudia Giacomozzi*, Claudio Carrara, Claudio Belvedere, Giada Lullini, Paolo Caravaggi, Stefano Durante, Lisa Berti, Giulio Marchesini, Luca Baccolini, Alberto Leardini
1:27-1:34pm	**Can preoperative weightbearing CT alignment predict postoperative patient reported outcomes in adult acquired flatfoot deformity?** Cesar de Cesar Netto, Katrina E Bang, Jonathan Garfinkel, Jonathan Day, Danilo Nishikawa, Guilherme Honda Saito, *Nacime Salomao Barbachan Mansur*, Jonathan Deland, Scott Ellis
1:34-1:41pm	**Hallux valgus deformity in patients with adult acquired flatfoot deformity: a weightbearing CT study** Katrina E Bang, Cesar de Cesar Netto, *Andrew Roney*, Alessio Bernasconi, Lauren Roberts, International WBCT Society, Carolyn Sofka, Jonathan Deland, Scott Ellis
1:41-1:48pm	**Posterior and Middle Facets of the Subtalar Joint: The Retrospective Search for an Early Sign of Peritalar Subluxation and Progressive Flatfoot Deformity** *Elijah Auch*, Thiago Alexandre Silva, Nacime Mansur, Shuyuan Li, Kevin Dibbern, John Femino, Daniel Baumfeld, Cesar de Cesar Netto
1:48-2:00pm	**Q&A**

2:10 - 2:30pm
(GMT-3)

Room 1

SPONSOR TIME LECTURE

Vicon motion capture for foot biomechanics – pre defined and custom modeling aproaches

Speakers: Felix Tsui and John Porter

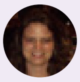
VICON

2:30 - 3:15pm (GMT-3)

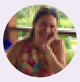
Room 1

Simultaneous translation available (EN-PT)

ORAL SESSION 2
Chronic Ankle Instability



Chair: Sandra Aliberti
Universidade de São Paulo



Chair: Eneida Yuri Suda
Universidade de São Paulo

2:30-2:37pm	**Increased jerk during a single-limb jump-stabilization task is associated with worse symptoms of ankle joint health among individuals with chronic ankle instability** *Kyle B. Kosik*, Kathryn Lucas, Matthew C. Hoch, Jacob T. Hartzell, Katherine A. Bain, Phillip A. Gribble
2:37-2:44pm	**The Effect of Attending Physical Rehabilitation After the First Acute Lateral Ankle Sprain on Landing Forces in Patients with Chronic Ankle Instability** *Matthew Hoch*, Jacob Hartzell, Katherine Bain, Phillip Gribble, Kyle Kosik
2:44-2:51pm	**The influence of footwear on lower-limb electromyography in individuals with chronic ankle instability during walking** *Gabriel Moisan*, Martin Descarreaux, Vincent Cantin
2:51-2:58pm	**Two weeks of anterior to posterior talocrural joint mobilizations do not change dorsiflexion at heel strike in those with chronic ankle instability** *Kimmery Migel*, M. Spencer Cain, Brian G. Pietrosimone, J. Troy Blackburn, Jason R. Franz, Kyeontak Song, Jaeho Jang, Erik A. Wikstrom
2:58-3:10pm	**Q&A**

3:15 - 3:25pm (GMT-3)

Break

3:25 - 3:45pm (GMT-3)

Room 1

SPONSOR TIME LECTURE
Load-Based Functional Recovery Following Total Ankle Arthroplasty

Robin Queen
Associate Professor
Biomedical Engineering and Mechanics and Orthopaedic Surgery
Director: Kevin Granata Biomechanics / Granata Treadmill Lab
Faculty Fellow: Office of the VP for Research and Innovation
Virginia Tech

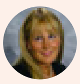
AMTI
FORCE AND MOTION

3:45 - 5:15pm (GMT-3)

Room 1

Simultaneous translation available (EN-PT)

SHORT COURSE
Gait Retraining for Running Injuries: Focus on the Foot

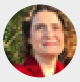


Irene Davis
Harvard Medical School, Cambridge

PROGRAM
MONDAY, APRIL 12, 2021

10:00 - 10:10am
(GMT-3)

Opening



Isabel Sacco
Universidade de São Paulo; President of i-FAB 2021

10:10 - 10:50am
(GMT-3)

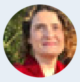
Room 1

Simultaneous translation available (EN-PT)

KEYNOTE SESSION 1

What's happening in my Achilles tendon? The effects of running in different footwear

Keynote speaker: Toni Arndt
The Swedish School of Sport and Health Sciences



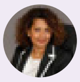
Chair: Isabel Sacco
Universidade de São Paulo; President of i-FAB 2021

10:55 - 11:50am (GMT-3)

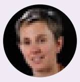
Room 1

Simultaneous translation available (EN-PT)

ORAL SESSION 3
Weight Bearing CT II



Chair: Rajshree Hillstrom
Biomed Consulting, Inc.



Chair: Sophie de Mits
Artevelde University of Applied Sciences

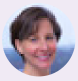
10:55-11:02am	**3D biometric weightbearing CT assessment of hindfoot alignment in adult aquired flatfoot deformity** *Cesar de Cesar Netto*, Katrina E Bang, Nacime Salomao Mansur, Jonathan Garfinkel, Danilo Nishikawa, Francois Lintz, Alessio Bernasconi, Jonathan Deland, Scott Ellis
11:02-11:09am	**Distal Tibiofibular Syndesmotic Widening in Progressive Collapsing Foot Deformity** *Elijah Auch*, Cesar de Cesar Netto, Thiago Alexandre Alves, Daniel Baumfeld, Nacime Mansur, Samuel Ahrenholz, Shuyuan Li, Kevin Dibbern
11:09-11:16am	**Foot alignment in symptomatic National Football League (NFL) athletes: a weightbearing CT analysis** Cesar de Cesar Netto, Katrina E Bang, Alexandre Leme Godoy-Santos, *Alessio Bernasconi*, Francois Lintz, Pedro Augusto Pontin, Lauren Roberts, Martin O'Malley
11:16-11:23am	**Motion of all foot bones under controlled vertical load from series of weight-bearing CT scans** *Michele Conconi*, Alessandro Pompili, Claudio Belvedere, Stefano Durante, Nicola Sancisi, Alberto Leardini
11:23-11:30am	**The efficacy of surgical treatment in the correction of adult acquired flatfoot deformity: a three-dimensional biometric weightbearing CT evaluation** *Cesar de Cesar Netto*, Jonathan Garfinkel, Katrina E Bang, Jonathan Day, Danilo Nishikawa, International WBCT Society, Scott Ellis, Martin O'Malley, Jonathan Deland
11:30-11:45am	**Q&A**

10:55 - 11:40am (GMT-3)

Room 2

Simultaneous translation available (EN-PT)

ORAL SESSION 4
Diabetic foot I



Chair: Mary K. Hastings
Washington University School of Medicine

Chair: Anne Rasmussen
Steno Diabetes Center Copenhagen

10:55-11:02am	**Digital foot health technology and diabetic foot monitoring: A systematic review** *Claire Saliba Thorne*, Cynthia Formosa, Alfred Gatt, Clifford DeRaffaele, Abduarahman Bazena
11:02-11:09am	**Gait analysis driven cluster analysis of diabetic patients: novel subgroups and their association with clinical outcomes in 15-years follow up** Annamaria Guiotto, Marco Soldan, Francesco Silvestri, *Fabiola Spolaor*, Gabriella Guarneri, Angelo Avogaro, Zimi Sawacha
11:09-11:16am	**Importance of measuring foot intrinsic and extrinsic muscle forces in diabetic subjects** *Alfredo Ciniglio*, Zimi Sawacha
11:16-11:23am	**The efficacy of a diabetic educational program and predictors of compliance of patients with non-insulin dependent diabetes mellitus (type 2)** *Kelly Cristina Stéfani*, Aldo Barbachan, Leonardo Moraes, Evandro Portes, Roberto Sacilotto
11:23-11:35am	**Q&A**

11:50am - 12:20pm (GMT-3)

Break

12:20 - 12:25pm (GMT-3)

Room 1

SPONSOR TIME DEMO

New Technologies Applied on Fila Running Performance Shoes

Speaker: Jonas de Araújo Rocha

12:25 - 12:30pm (GMT-3)

Room 1

SPONSOR TIME DEMO

High precision for foot and ankle biomechanics

Speaker: Orlando Orlandi Melo de Carvalho

12:30 - 1:10pm (GMT-3)

Room 1

Simultaneous translation available (EN-PT)

KEYNOTE SESSION 2

Biomechanics, physics, and evolution of foot arches

The stiffness of the foot is important to support the forces of walking and running. In this talk, I show how the arches of the human foot enable such stiffness. In particular, the transverse arch of the tarsals in the midfoot is a crucial part of the foot's stiffness due to the principle of curvature-induced stiffness. Using mathematical models, physical mimics, and biological experiments we show how the transverse arch stiffens the foot. The principle is evident in a drooping currency note that significantly stiffens upon slightly curling it in the transverse direction.

Keynote speaker: Madhusudhan Venkadesan
Yale University, Connecticut

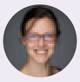
Chair: William Ledoux
CLiMB, VA Center for Limb Loss and MoBility, Washington

1:15 - 2:20pm (GMT-3)

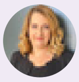
Room 1

Simultaneous translation available (EN-PT)

ORAL SESSION 5
Foot Biomechanics



Chair: Julie Stebbins
Oxford University Hospitals



Chair: Deyse Borges Machado
Universidade Estadual de Santa Catarina

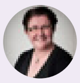
1:15-1:22pm	**Fine-wire electromyography of the transverse head of adductor hallucis during locomotion** *Kelly Robb*, Melady, Hope, Stephen, Perry
1:22-1:29pm	**Open kinematic chain motion of the sesamoids in dorsiflexion** Mackenzie M. French, Eric D. Thorhauer, Tadashi Kimura, Bruce J. Sangeorzan, *William R. Ledoux*
1:29-1:36pm	**Plantar pressure sensors configurations to meet different applications** *Alfredo Ciniglio*, Annamaria Guiotto, Zimi Sawacha
1:36-1:43pm	**The foot becomes less spring-like as speed increases** *Lauren Williams*, Dustin Bruening, Spencer Petersen
1:43-1:50pm	**The impact of leg dominance on plantar pressure measurements: A STAPP study** *Brian Booth*, Jan Sijbers, Noel keijsers
1:50-1:57pm	**The midfoot joint complex is functionally coordinated with the other lower limb joints for gait forward progression** *Thales R Souza*, Paula M Arantes, Leonardo D Barsante, Fabrício A Magalhães, Sérgio T Fonseca
1:57-2:15pm	**Q&A**

1:15 - 2:10pm (GMT-3)

Room 2

Simultaneous translation available (EN-PT)

ORAL SESSION 6
Tissue Biomechanics



Chair: Claire Brockett
University of Leeds

Chair: Heiliane de Brito Fontana
Universidade Federal de Santa Catarina

1:15-1:22pm	**Acceleration of the centre of mass of the body increases heel fat pad deformation and energy absorption** *Lauren Welte*, Toni Arndt, Michael J Rainbow
1:22-1:29pm	**Exercise as a mechanical trigger followed by collagenase injections replicating intrinsic factors: an evolution of the animal model of chronic Achille's tendinopathy** *Cesar de Cesar Netto*, Mario Lobao, Katrina E Bang, Kyle Duchman, John Femino, Jessica Goetz, Zijun Zhang, Lew Schon
1:29-1:36pm	**Obesity, muscle quality and plantar fascia thickness in healthy adults** *Juliana Yasmin Passos Karam*, Jonathan Neto Müller, Heiliane de Brito Fontana
1:36-1:43pm	**Reliability in ultrasound measurements of plantar aponeurosis thickness** *Thiago de Souza da Silva*
1:43-1:50pm	**There is no difference between 2 and 5 minutes of static stretching on the mechanical properties of the Achilles tendon** *Francesca Sonda*, Anelize Cini, Emmanuel Souza da Rocha, Mariana de Oliveira Borges, Claudia Silveira Lima, Marco Aurélio Vaz
1:50-2:05pm	**Q&A**

2:20 - 2:30pm (GMT-3)

Break

2:30 - 2:40pm (GMT-3)

Room 1

SPONSOR TIME DEMO

Title: Ebers System: gait analysis in the office

Speaker: M.D. Gabriela Blumtritt

2:40 - 4:30pm (GMT-3)

Room 1

Simultaneous translation available (EN-PT)

SPECIAL SESSION 1

Diabetic Foot Biomechanics

Chair: David G. Armstrong

Keck School of Medicine of University of Southern California

Chair: Sicco Bus

University of Amsterdam

2:40-3:00pm	**Surgical offloading and biomechanical wearables** David G. Armstrong
3:00-3:05pm	**Q&A**
3:05-3:12pm	**The diabetic foot prevention: how model-based assessment of plantar tissues internal stresses can inform clinical practice** *Annamaria Guiotto*, Zimi Sawacha
3:12-3:19pm	**Peripheral Neuropathy, Claw Toes, Intrinsic Muscle Volume, and Plantar Aponeurosis Thickness in Diabetic Feet** Tadashi Kimura, Eric D. Thorhauer, Matthew W. Kindig, Bruce J. Sangeorzan, *William R. Ledoux*
3:19-3:26pm	**Differences in mechanical skin properties as a compensatory mechanism of sensory impairment in Diabetes patients?** *Tina J. Drechsel*, Claudio Zippenfennig, Renan L. Monteiro, Isabel C. N. Sacco, Thomas L. Milani
3:26-3:33pm	**Heel rise task identifies midfoot function during walking in diabetes** *Hyo-Jung Jeong*, Michael J. Mueller, Jennifer A. Zellers, Yan Yan, Mary K. Hastings
3:33-3:40pm	**Clinical relevance of the plantar anatomical masking for plantar loading analysis in Diabetic Foot** *Erica Silva*, Renan Monteiro, Danilo Santos, Jane Ferreira, Isabel Sacco, Claudia Giacomozzi
3:40-3:47pm	**Biomechanics of midfoot Charcot neuroarthropathy in people with diabetes** *Nichola Renwick*, Esther Smith, Jim Woodburn, Kenneth Meijer, Roslyn Miller, James Harper
3:47-4:05pm	**Q&A (all presentations)**
4:05-4:20pm	**State of the art in footwear biomechanics in diabetic foot disease** Sicco Bus
4:20-4:24pm	**Q&A**

4:35 - 5:20pm
(GMT-3)

Room 1

Simultaneous translation available (EN-PT)

ORAL SESSION 7

Kinematics Methodological Aspects I

Chair: Karine Jacon Sarro
UNICAMP - Universidade Estadual de Campinas

Chair: Alessandra Bento Matias
Universidade de São Paulo

4:35-4:42pm	**Accuracy and reliability of skin-markers based measures of the medial longitudinal arch of the foot** *Paolo Caravaggi*, Alberto Leardini, Isabel Sacco, Ulisses Taddei, Alessandra Matias, Chiara Spasiano, Mariachiara Barbieri, Giulia Rogati, Maurizio Ortolani
4:42-4:49pm	**Analysis of intra-examiner reproducibility in the analysis of 2D Ankle Kinematics** *Felipe P Carpes*, Jean S Carvalho, Victor L Costa, Carolina S Martins, Eliane C Guadagnin
4:49-4:56pm	**Development and Validation of a Multi-Segment Foot Model using Biplanar Videoradiography** *Jayishni Maharaj*, Michael J Rainbow, Dominic Gehring, Glen A Lichtwark
4:56-5:03pm	**Forefoot subdivision and kinematics for clinical gait analysis** Po-Hsiang Chan, Julie Stebbins, *Amy B. Zavatsky*
5:03-5:15pm	**Q&A**

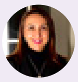
4:35 - 5:20pm
(GMT-3)

Room 2

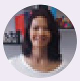
Simultaneous translation available (EN-PT)

ORAL SESSION 8

Sports



Chair: Andresa Germano
Chemnitz University of Technology



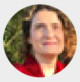
Chair: Liu Chiao Yi
Unifesp

4:35-4:42pm	**Correlation between stabilometry and history of sprains in professional volleyball athletes** *Thania Loiola Cordeiro Abi Rached*, Alexandre Collucci, Tales Triani, Rogerio Bitar
4:42-4:49pm	**Force-time curves and plantar pressure distribution in high level athletes of 400 metres hurdles in block phase** *Paulo H. P. Rodrigues*, Lyon Aragão, Elias Nicolas, Evandro Lázari, Ricardo M. L. Barros
4:49-4:56pm	**The influence of foot alignment and ankle dorsiflexion range of motion on dynamic lower limb valgus during a classical ballet jump: a cross-sectional study** *Anelise Moreti Cabral*, Adalberto Felipe Martinez, Vitor Leme, Bruna Calazans Luz, Fábio Viadanna Serrão
4:56-5:03pm	**Relationship between Achilles tendon properties, metabolic cost and 3000 m running performance** *Esthevan Machado*, Edson S Silva, Fábio J Lanferdini, Jeam M Geremia, Leonardo A Peyré-Tartaruga
5:03-5:15pm	**Q&A**

PROGRAM
TUESDAY, APRIL 13, 2021

10:00 - 10:10am
(GMT-3)

Opening



Isabel Sacco
Universidade de São Paulo; President of i-FAB 2021

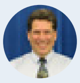
10:10 - 10:50am
(GMT-3)

Room 1

Simultaneous translation available (EN-PT)

KEYNOTE SESSION 3
Investigation of Human Foot Function Using Approaches in Imaging and Musculoskeletal Modeling

Keynote speaker: Michael Rainbow
Queen's University, Kingston



Chair: Howard Hillstrom
Motion Analysis Laboratory, New York City

10:50 - 11:10am
(GMT-3)

Room 1

SPONSOR TIME DEMO
Novel Customer Applications in Foot and Ankle

Speakers: Scott Ellis MD, Robin Queen PhD and Sicco Bus PhD

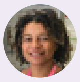
novel

11:15am - 12:20pm (GMT-3)

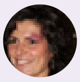
Room 1

Simultaneous translation available (EN-PT)

ORAL SESSION 9
Foot-Ankle Modelling



Chair: Zimi Sawacha
University of Padova



Chair: Fabiola Spolaor
University of Padova

11:15-11:22am	**Design of dynamic foot function models: a finite element and machine learning approach** Tristan Tarrade, Maxime Llari, Dorian Salin, *Michel Behr*
11:22-11:29am	**Excessive stiffness interrupts alleviation of stress on the heel pad: Finite element analysis** *Dahae Min*, Hamin Lim, Haeun Yum, Taeyong Lee
11:29-11:36am	**FEM driven workflow for virtually optimized insole** *Annamaria Guiotto*, Marco Galuppo, Giorgia Sartorato, Zimi Sawacha
11:36-11:43am	**Implant fixation influences tibial bone strain after total ankle replacement: A finite element study** *Bryony Halcrow*, Ruth K Wilcox, Claire L Brockett
11:43-11:50am	**Searching an alternative to the triple arthrodesis for flatfoot deformity correction: A finite element analysis.** *Christian Cifuentes De la Portill-*, Ricardo Larrainzar-Garijo, Javier Bayod, Marco A. Martínez Bocanegra
11:50-11:57am	**Subject-Specific Prediction of Soft Tissue Structures In The Ankle Joint** *Matthias Peiffer*, Matthias Last, Emmanuel Audenaert, Arne Burssens, Sophie De Mits, Jan Victor
11:57am-12:15pm	**Q&A**

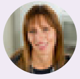
11:15am - 12:20pm (GMT-3)

Room 2

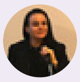
Simultaneous translation available (EN-PT)

ORAL SESSION 10

Orthopedics I (surgical aspects)



Chair: Elizabeth Pedersen
University of Alberta Hospital



Chair: Ana Paula Simões
Hospital Santa Casa de São Paulo

11:15-11:22am	**Biomechanical Evaluation of Arthroplasty in the First Ray of the Foot** *Mario Alberto Madrid Pérez*
11:22-11:29am	**Contralateral ankle complex kinematic compensations after unilateral tibiotalar arthrodesis** *Amy L. Lenz*, Jennifer A. Nichols, Koren E. Roach, Rich J. Lisonbee, K. Bo Foreman, Alexej Barg, Charles L. Saltzman, Andrew E. Anderson
11:29-11:36am	**Percutaneous Distal Metatarsal Mini-invasive Osteotomy: Comparison between Standard versus Modified Intraosseous Approach - A Cadaveric Study** *Elijah Auch*, Cesar de Cesar Netto, Shuyuan Li, Fernando Martins, Victoria Vivtcharenko, Eli Schmidt, Alexandre Godoy-Santos, John Femino
11:36-11:43am	**The influence of calcaneal and first ray osteotomies in the contact pressures of the ankle joint** *Cesar de Cesar Netto*, Danilo Ryuko Nishikawa, Pooyan Abbasi, Katrina E Bang, Niall Smyth, Nicholas Casscells, Stuart Michnick, Gao Zhengyu, Constantine Demetracopoulos, Brent Parks, Stuart Miller
11:43-11:50am	**The use of three-dimensional (3D) biometric measurements to predict ddditional alignment procedures in total ankle replacement** *Cesar de Cesar Netto*, Alexandre Leme Godoy-Santos, Katrina E Bang, Jonathan Garfinkel, Jonathan Day, International WBCT Society, Scott Ellis, Jonathan Deland, Constantine Demetracopoulos
11:50-11:57am	**Validation of a biomechanical model of the human ankle joint for personalised orthopaedic treatments via a dynamic simulation approach** *Daisy Ferraro*, Alberto Leardini, Claudio Belvedere, Paolo Caravaggi, Maria Ruiz, Sorin Siegler
11:57am-12:15pm	**Q&A**

12:20 - 12:50pm (GMT-3)

Break

12:50 - 1:00pm (GMT-3)

Room 1

SPONSOR TIME DEMO

Capturing Pediatric Natural Gait Using In-Shoe Plantar Pressure

Speaker: Michael Haley, Knowledge Transfer Partnership (KTP) Associate (Centre for Health Sciences Research, University of Salford and C. & J. Clark International, Ltd.)

XSENSOR | Intelligent Dynamic Sensing

1:00 - 2:15pm (GMT-3)

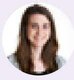
Room 1

Simultaneous translation available (EN-PT)

ORAL SESSION 11

Footwear/ Orthotics

Chair: Sharon Dixon
University of Exeter



Chair: Carina Price
University of Salford

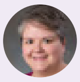
1:00-1:07pm	**Effects of three types of foot orthoses on the knee joint of posterior tibialis tendon dysfunction population** *Dominic*, Philippe Corbeil, Étienne Belzile, Marc Bouchard, Simon Laurendeau
1:07-1:14pm	**Influence of foot orthotics on fifth metatarsal strains in gait** *Jeffrey W. Hoffman*, Rogerio Bitar, Daniel R. Sturnick, Glenn Garrison, Constantine Demetracopoulos, Mark Drakos, M.D, Martin O'Malley
1:14-1:21pm	**Long-term effects of medial-wedged insoles in over-pronated feet on the lower limb kinematics during walking: preliminary results** *Fabrício Anicio Magalhães*, Fernanda Muniz Vieira, Caroline Kokudai Reis, Brunna Librelon Costa, Bianca Martins Lourenço, Renan Resende Alves, Renato Guilherme Trede Filho
1:21-1:28pm	**Prescribing custom dynamic orthoses to reduce risk of post-traumatic OA after tibial pilon fractures** Bryan D. Tanner, Jason M. Wilken, Kirsten M. Anderson, *Donald D. Anderson*
1:28-1:35pm	**The effect of a split outsole on intrinsic foot kinematics and lower leg muscle activities during normal walking** *Hamin Lim*, Jihyeon Jeon, Dahae Min, Taeyong Lee
1:35-1:42pm	**The effect of footwear on arch-ligament dynamics: a pilot study** Michael Pearce, *Lauren Welte*, Toni Arndt, Michael J Rain
1:42-1:49pm	**The number of trials required to estimate a representative foot loading pattern** Shaquille Charles, Milad Zarei, Ashika Mani, Gehui Zhang, Robert Krafty, MaCalus V. Hogan, *William Anderst*
1:49-2:10pm	**Q&A**

1:00 - 2:15pm
(GMT-3)

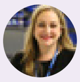
Room 2

Simultaneous translation available (EN-PT)

ORAL SESSION 12
Pediatrics



Chair: Kirsten Tulchin Francis
Texas Scottish Rite Hospital for Childrez



Chair: Cylie Williams
Monash University

1:00-1:07pm	**A preliminary analysis of plantar pressure data in infants at the onset of walking and confidently walking using pedobarographic statistical parametric mapping (pSPM)** *Eleonora Montagnani*, Dr Carina Price, Prof Chris Nester, Dr Stewart Morrison
1:07-1:14pm	**Effectiveness of children's therapeutic stability footwear: A Delphi consensus on outcome measures** *Matthew Hill*, Aoife Healy, Nachiappan Chockalingam
1:14-1:21pm	**Effect of plantar flexor muscle strengthening on the gait of children with idiopathic toe walking: preliminary results** *Liu Chiao Yi*, Vanessa Gonçalves Coutinho de Oliveira, Lucas Simões Arrebola, Pedro Rizzi de Oliveira
1:21-1:28pm	**Investigation of muscle strength, motor coordination and balance in children with idiopathic toe walking: analytical cross-sectional study** *Vanessa Oliveira*, Liu Chiao Yi, Lucas Simões Arrebola, Pedro Rizzi de Oliveira
1:28-1:35pm	**Redefining the Juvenile Bunion** Caitlin Hardin, Claire Shivers, Kirsten Tulchin-Francis, Chanhee Jo, *Anthony I Riccio*, Jacob R Zide
1:35-1:42pm	**Soft soled footwear has limited impact on toddler gait** *Cylie Williams*, Jessica Kolic, Wen Wu, Kade Paterson
1:42-1:49pm	**The effect of heel height on initial contact in children** *Michael Haley*, Carina Price, Anmin Liu, Chris Nester
1:49-2:10pm	**Q&A**

2:20 - 2:30pm
(GMT-3)

Break

2:30 - 2:40pm (GMT-3)

Room 1

SPONSOR TIME DEMO

BaroScan – Your baropodometry system

Speaker: Daniel Camargo

BARO SCAN

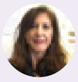
2:40 - 3:35pm (GMT-3)

Room 1

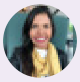
Simultaneous translation available (EN-PT)

ORAL SESSION 13

Diabetic foot II



Chair: Claudia Giacomozzi
Italian National Institute of Health



Chair: Érica Queiroz da Silva
Universidade de São Paulo

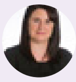
2:40-2:47pm	**EMG alteration in diabetes subjects with and without neuropathy varies across different tasks: comparison among EMG activity in overground, treadmill walking and stair negotiation** *Weronika Joanna Piatkowska*, Fabiola Spolaor, Annamaria Guiotto, Gabriella Guarneri, Angelo Avogaro, Zimi Sawacha
2:47-2:54pm	**People with diabetes mellitus and peripheral neuropathy have limited ability to plantarflex their foot and ankle during heel rise tasks** *Hyo-Jung Jeong*, Michael J. Mueller, Jennifer A. Zellers, Yan Yan, Mary K. Hastings
2:54-3:01pm	**Plantar pressures and adherence in a combination of indoor and regular custom-made footwear for people with diabetes at high risk of foot ulceration** *Jaap J. van Netten*, Renske Keukenkamp, Tessa Busch-Westbroek, Sicco A. Bus
3:01-3:08pm	**Plantar soft tissue mechanics is different in diabetes and pre-diabetes and is related to the measures associated with hyperglycemia level** *Roozbeh Naemi*, Stefano Enrique Romero Gutierrez, David Allan, Juvenal Ormaechea, Evelyn Gutierrez, Jessica Casado-Pena, Sharon Anyosa-Zavaleta, Mauricio Juarez, Fanny Casado, Benjamin Castaneda Aphan, Gilmer Flores
3:08-3:15pm	**Type II diabetes and peripheral neuropathy in older adults postural sway outcomes: Nintendo Wii balance board as a clinical tool** *Martin Vargas Matamala*, Juan Guerrero-Henríquez, David Coo-Aqueveque, Francisco Salvador Sagüez
3:15-3:30pm	**Q&A**

2:40 - 3:35pm (GMT-3)

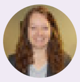
Room 2

Simultaneous translation available (EN-PT)

ORAL SESSION 14
Kinematics Methodological Aspects II



Chair: Elyse Passmore
The Royal Children's Hospital and Murdoch Children's Research Institute



Chair: Amy L. Lenz
University of Utah

2:40-2:47pm	**A comparison of a multi-segment foot model to a one-segment foot model during balance tasks** *Lena Fennen*, Rosemary Dubbeldam, Heiko Wagner
2:47-2:54pm	**Comparison of the rigidity and forefoot – rearfoot kinetics from three forefoot tracking marker clusters during the stance phase of walking** *Fabrício A Magalhães*, Thales R Souza, Vanessa L Araújo, Lílian M Oliveira, Letícia P Silveira, Juliana M Ocarino, Sérgio T Fonseca
2:54-3:01pm	**Longitudinal plantar arch stiffness during running by different arch definitions** *Ulisses Taddei*, Alessandra Matias, Paolo Caravaggi, Isabel CN Sacco
3:01-3:08pm	**Marker placement sensitivity in the Oxford and Rizzoli Foot Models** *Wouter Schallig*, Josien van den Noort, Geert Streekstra, Mario Maas, Jaap Harlaar, Marjolein van der Krogt
3:08-3:15pm	**Subject-specific geometric definition and validation of a novel kinematic model of human hind+midfoot** Maurizio Brocato, Paolo Podio-Guidugli, *Nicola Sancisi*, Michele Conconi, Claudio Belvedere, Vincenzo Parenti-Castelli, Alberto Leardini
3:15-3:30pm	**Q&A**

3:40 - 3:50pm (GMT-3)

Break

3:50 - 4:00pm (GMT-3)

Room 1

SPONSOR TIME DEMO

QUALISYS
Motion Capture Systems

4:00 - 5:05pm (GMT-3)

Room 1

Simultaneous translation available (EN-PT)

ORAL SESSION 15

Clinical Biomechanics I

Chair: Rosemary Dubbeldam
University of Muenster

Chair: Lena Fennen
Westfälische Wilhelms-Universität Münster

4:00-4:07pm	**Does the alteration in binocular fusion modify spontaneous walking? (Pilot Study)** Pellegrini Manon, Biteau Mélanie, Paillard Thierry, *Marc Janin*, Bosquet Laurent
4:07-4:14pm	**Eye-foot coordination in normal aging and mild cognitive impairment (MCI)** *Andresa M. C. Germano*, Daniel Schmidt, Thomas L. Milani
4:14-4:21pm	**Isolated gastrocnemius tightness: impact on foot diseases** *Kelly Cristina Stéfani*, Leonardo Moraes, Gabriel F Ferraz, Vinicius Quadros Borges
4:21-4:28pm	**Objective mechanical measures predict post-traumatic OA risk after intra-articular fracture of the hindfoot and ankle** *Kevin N Dibbern*, Karan Rao, Molly Day, Michael C Willey, J. Lawrence Marsh, Donald D. Anderson
4:28-4:35pm	**Plantar Irritating Stimuli. Have they the same physiological support?** *Marc Janin*
4:35-4:42pm	**Twelve weeks of eccentric training do not improve calf muscle isometric torque after Achilles tendon rupture** *Emmanuel Souza da Rocha*, Francesca C Sonda, Klauber D Pompeo, Jeam M Geremia, Marco A Vaz
4:42-5:00pm	**Q&A**

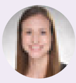
4:00 - 4:45pm (GMT-3)

Room 2

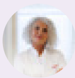
Simultaneous translation available (EN-PT)

ORAL SESSION 16

Kinematics Methodological Aspects II



Chair: Ruth L. Chimenti
University of Iowa



Chair: Isabelle Van Dalen
Bergmanclinics

4:00-4:07pm	**Coverage and Congruity Analysis of the Articulating Surfaces in the Ankle Joint** *Maria Ruiz*, Jordan Stole, Dhwanit Vispute, Francois Lintz, Cesar Netto, Rena Mathew, Sorin Siegler
4:07-4:14pm	**Functional Implications of the Flat-Topped Talus Following Treatment of Idiopathic Clubfoot Deformity** Matthew J Siebert, Claire Shivers, Jacob R Zide, Kirsten Tulchin-Francis, Wilshaw Stevens Jr, Justine Borchard, *Anthony I Riccio*
4:14-4:21pm	**Is first ray hypermobility related to the flat foot?** *Oliver J Morgan*, Howard J Hillstrom, Robert Turner, Jonathan Day, Scott Ellis, Jonathan T Deland, Rajshree Hillstrom
4:21-4:28pm	**Quantitative analysis of talar dome morphology** Justine Borchard, Wilshaw Stevens Jr, Matthew J Siebert, Claire Shivers, Jacob R Zide, Anthony I Riccio, *Kirsten Tulchin-Francis*
4:28-4:40pm	**Q&A**

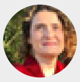
5:15pm (GMT-3)

FABParty

PROGRAM
WEDNESDAY, APRIL 14, 2021

10:00 - 10:10am
(GMT-3)

Opening



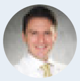
Isabel Sacco
Universidade de São Paulo; President of i-FAB 2021

10:10 - 10:50am
(GMT-3)

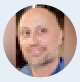
Room 1

Simultaneous translation available (EN-PT)

KEYNOTE SESSION 3
The Collapsing Foot: Challenges in Diagnosis & Treatment & The Role of the Weight-Bearing CT



Keynote speaker: Cesar de Cesar Netto
University of Iowa, Iowa City-IA



Chair: Paolo Caravaggi
IRCCS Istituto Ortopedico Rizzoli, Bologna

10:55am - 12:45pm
(GMT-3)

Room 1

Simultaneous translation available (EN-PT)

SPECIAL SESSION 2
Weight-Bearing CT

Chair: Francois Lintz
International WBCT Society

Chair: Alberto Leardini
IRCCS Istituto Ortopedico Rizzoli, Bologna

10:55-11:15am	**Technical and Clinical aspects of WBCT based scans and analyses** Francois Lintz and Alberto Leardini
11:15-11:20am	**Q&A**
11:20-11:27am	**New 3D angular measurements of foot bones in weight-bearing: the technique and preliminary clinical cases** Claudio Belvedere, Paolo Caravaggi
11:27-11:34am	**3D joint space width from weight bearing CT detects progressive narrowing after tibial pilon fractures** Erin McFadden, Michael Ho, Kevin Dibbern, Michael Willey, Julie Agel, Conor Kleweno, Justin Haller, Thomas Higgins, J. Lawrence Marsh, Donald D. Anderson
11:34-11:41am	**Ankle joint weightbearing CT three-dimensional distance maps of adult-acquired flatfoot deformity: a retrospective case-control study** Victoria Vivtcharenko, Kevin Dibbern, Shuyuan Li, Elijah Auch, Eli Schmidt, John Femino, Cesar de Cesar Netto
11:41-11:48am	**High Resolution 3D Weight Bearing Imaging of Foot & Ankle: Implications for Near Term and Long-Term** Shadpour Demehri
11:48-11:55am	**In vivo changes in distal interosseous tibiofibular ligament elongation under static loads and during dynamic activities after syndesmosis repair** Stephen Canton, William Anderst, MaCalus Hogan, Tom Gale, Chukwudi Onyeukwu
11:55am-12:02pm	**WBCT and Achilles tendinopathy and the continued search for pain mechanisms** Ruth Chimenti, Kevin N Dibbern, Nacime S Barbachan Mansur, Cesar de Cesar Netto
12:02-12:09pm	**The rotational positioning of the bones in the medial column of the foot: a weightbearing CT analysis** Eli Schmidt, Thiago Alexandre Silva, Shuyuan Li, Elijah Auch, Victoria Vivtcharenko, Nacime Mansur, Cesar de Cesar Netto
12:09-12:16pm	**How important is WBCT in hallux decision** Cristian Ortiz
12:16-12:40pm	**Q&A (all presentations)**

12:45 - 1:15pm
(GMT-3)

Break

1:15 - 1:20pm
(GMT-3)

Room 1

SPONSOR TIME DEMO

The Foundations and Evolution of sEMG Decomposition Technologies

Speaker: Steven Lindley, Ph.D.

DELSYS

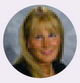
1:20 - 2:35pm
(GMT-3)

Room 1

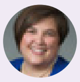
Simultaneous translation available (EN-PT)

ORAL SESSION 17

Running



Chair: Irene Davis
Harvard Medical School, Cambridge



Chair: Sarah Ridge
BYU College of Life Sciences

1:20-1:27pm	**Association between foot mobility and strength of the foot's intrinsic muscles in recreational runners: a cross-sectional study** *Antonio Carlos Ferraz de Andrade*, Thiago F Santos, Eduardo B Junqueira, Paulo R P Santiago
1:27-1:34pm	**Can foot-ankle movement patterns be used to distinguish running experience levels?** Eneida Yuri Suda, *Ricky Watari*, Alessandra B Matias, Isabel C N Sacco
1:34-1:41pm	**Differences in vertical stiffness and center of mass excursion between runners with a rearfoot and forefoot strike pattern** *Caleb D Johnson*, Irene S Davis
1:41-1:48pm	**Effect of a high-intensity interval training in the ankle kinematics during a treadmill protocol in amateur runners** Vitor Arpini, *Bruno Bedo*, Rodrigo Aquino, Carlos Augusto Kalva-Filho, Eduardo Bergonzoni, Paulo R P Santiago
1:48-1:55pm	**Effects of a foot-ankle exercises protocol on lower extremity kinetics and kinematics during running: results of a randomized controlled trial** *Alessandra Matias*, Ulisses Taddei, Paolo Caravaggi, Rafael Inoue, Raissa Thibes, Isabel Sacco
1:55-2:02pm	**Effects of foot-core strengthening on the lower extremity distal power output during running: results of a randomized controlled trial** Lucas Santana da Silva, Marcos Duarte, Renato Watanabe, Alessandra Matias, Ulisses Taddei, Ricky Watari, Isabel Sacco, *Reginaldo Fukuchi*
2:02-2:09pm	**Mechanical risk factors for predicting stress fracture in elite runners** *Andrew R Wilzman*, Karen L. Troy, Michael Fredericson, Nate Wilcox-Fogel, Meagan Roche, Emily Kraus, Adam S. Tenforde
2:09-2:30pm	**Q&A**

2:40 - 2:45pm
(GMT-3)

Break

2:45 - 3:05pm (GMT-3)

Room 1

SPONSOR TIME DEMO

HiRise: Enabling 3D Biomechanical Research for the Entire Lower Extremity

Presented by: Kevin Dibbern, PhD; Cesar de Cesar Netto, MD, PhD; Donald Anderson, PhD; Michael Willey, MD; Ruth Chimenti, DPT, PhD

Moderated by: Jenna Roller, CurveBeam

CurveBeam

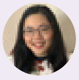
3:05 - 4:00pm (GMT-3)

Room 1

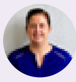
Simultaneous translation available (EN-PT)

ORAL SESSION 18

Clinical Biomechanics II



Chair: Thanaporn Tunprasert
University of Brighton



Chair: Aoife Healy
Staffordshire University

3:05-3:12pm	**Adaptative strategies to reduced ankle dorsiflexion range of motion** Mariana R C Aquino, Sérgio T Fonseca, Thales R Souza, Renan A Resende, Juliana M Ocarino
3:12-3:19pm	**Ankle dorsiflexion range of motion is related to pelvis kinematics during gait** Mariana R.C. Aquino, Renan A. Resende, Clara C. Fajardo, Suelen C.S. Martins, Sérgio T Fonseca
3:19-3:26pm	**Individual differences in intrinsic ankle stiffness: their relationship to body sway and ankle torque** Tania Emi Sakanaka, Martin Lakie, Raymond F. Reynolds
3:26-3:33pm	**Plantar pressure patterns are associated with lower leg complaints in military recruits** Noel Keijsers, Minke Ter Stal, Niels Jonkergouw, Pieter Helmhout
3:33-3:40pm	**The effect of induced joint restriction on plantar pressure distribution** Erica Bartolo
3:40-3:55pm	**Q&A**

4:05 - 4:45pm (GMT-3)

Room 1

Simultaneous translation available (EN-PT)

KEYNOTE SESSION 5

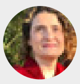
The Foot Core Paradigm: Let's Think Differently about the Foot

Keynote speaker: Irene Davis
Harvard Medical School, Cambridge

Chair: Sicco Bus
University of Amsterdam

4:50 - 5:10pm (GMT-3)

Closing Ceremony



Isabel Sacco
Universidade de São Paulo; President of i-FAB 2021

MCG SYMPOSIUM
Symposium of the ISB Technical Group in Motor Control

Date: April 11, 2021 | Time: 10:00 am – 12:30 pm (UTC -3)

The symposium on Motor Control in Biomechanics is a forum to foster the growing interest in scientific work that bridges the fields of Motor Control and Biomechanics. The symposium is organized by the ISB Technical Group in Motor Control (http://www.mcg.isbweb.org/) and brings together internationally renowned speakers to introduce their work on the understanding and application of motor control principles and approaches with a focus on foot and ankle biomechanics for a range of applications including Sports Medicine, Rehabilitation, Kinesiology, Modeling, and more.
Researchers and students with an interest in Biomechanics and Motor Control will have the opportunity to discover the latest developments at the intersection of these fields and discuss with experienced investigators.

Speakers:

Model-based comparative biomechanics and muscle function analysis of simulated crouch gait by healthy children and crouch gait in CP children

Antonio Veloso, University of Lisbon (Portugal)

António Veloso is Full Professor at the University of Lisbon, since 2010. He is the Director of the PhD Program in Kinesiology at the Faculty of Human Kinetics from the University of Lisbon, also been responsible for the PhD in Biomechanics of this program since 2011 being also the director of the Biomechanics and Functional Morphology Laboratory of the University of Lisbon. He has served as Vice Dean at the Faculty of Human Kinetics of the University of Lisbon, between 2005 and 2009. Was also Head of Sports and Health Department at the same institution from 2012 until 2016.
António served as President for the Portuguese Society of Biomechanics between 2005-2009, as member of the Board of Directors for the International Society of Biomechanics in Sports for three terms between 2005-2011 and more recently served 6 years as member of the executive council of the International Society of Biomechanics where he was responsible for the programs for the ISB affiliated societies, the ISB technical groups and also the ISB EDC countries support programs.
António has published more than 200 papers in peer reviewed academic journal and in congress proceedings. His research interests include the biomechanics of human movement, where he focuses on the development of experimental methodologies, including the modelling and simulation of mechanical loads on the musculoskeletal system.

Motor control alterations in diabetic neuropathy: insights for rehabilitation strategies

Eneida Yuri Suda, Universidade de São Paulo (Brazil)

Eneida Yuri Suda has a BSc (2000) in Physical Therapy with a MSc (2006) and PhD degrees (2017) in Sciences from the University of São Paulo, Brazil, with a one-year internship at Aalborg University, Denmark (2015-16). She is currently a full-time post-doctoral fellow at Laboratory of Biomechanics of Movement and Human Posture from University of São Paulo, Brazil. She has been working with research in Biomechanics since 2003, and her main research areas of interest are biomechanical analysis of the human movement and detection, processing and interpretation of surface EMG, motor control, foot-ankle biomechanics, biomechanics and rehabilitation of diabetic patients.

Motor control at the ankle joint: neuromuscular adaptations to training and injury

Marco Vaz, Universidade Federal do Rio Grande do Sul (Brazil)

Dr. Marco Vaz is a Professor at the Federal University of Rio Grande do Sul, Brazil. He received his B.Sc. in Physical Education by the School of Physical Education, Physical Therapy and Dance of the same university in 1985, and his Ph.D. from the University of Calgary, Canada in 1996. He is presently a member of the World Council of Biomechanics, and has been a member of the International Society of Biomechanics Executive Council from 2009 to 2015. He has also been the President of the Brazilian Society of Biomechanics from 2011 to 2015. His current research focuses on developing a basic understanding of the Biomechanics of Human Movement, with special emphasis on neuromuscular plasticity due to increased- and decreased-use models, neuromuscular electrical stimulation and clinical models related to lower limb injuries.

Biomechanics and motor control of challenged gait in older adults

Eliane Celina Guadagnin, Universidade Federal do Pampa (Brazil)

Dr. Eliane Celina Guadagnin completed her Ph.D. in Human Movement Sciences in 2018 from Federal University of Rio Grande do Sul (Brazil). Currently, she is a post-doctoral fellow at the Federal University of Pampa (Brazil). Her research are mainly focused on the effects of aging on gait under challenging conditions, on muscle structure, and on muscle function, and she is also interested in understanding how these parameters interact with each other and what is the influence of exercise on them.

The midfoot passive mechanical properties affect the lower limb biomechanics in weight-bearing activities

Fabrício Magalhães, Federal University of Minas Gerais (Brazil)

Fabrício Magalhães earned a Bachelor degree in Physical Therapy from Pontifical Catholic University of Minas Gerais (PUCMG, Brazil), a Specialization in Physical Therapy with an emphasis in Sports and Therapeutic Exercises from PUCMG (Brazil), a Master degree in Sports Sciences (applied field: Sports Biomechanics) from Federal University of Minas Gerais (UFMG, Brazil), a Doctorate in Bioengineering (applied field: Biomechanics) from Università di Bologna (UNIBO, Italy), and Post-Doctoral residency in Rehabilitation Science (applied field: Motion Analysis) from UFMG (Brazil). He has experience in Biomechanics, Kinesiology, Orthopedics, Rehabilitation, Bioengineering and Sports, and currently, he is the human motion analysis laboratory's manager at UFMG, author of dozens of articles and reviewer of some high-impacted scientific journals.

SHORT COURSE

Gait Retraining for Running Injuries: Focus on the Foot

Date: April 11, 2021 | Time: 3:45 pm - 5:15 pm (UTC -3)

Irene Davis

Harvard Medical School, Cambridge

CONFIRMED KEYNOTES

Toni Arndt

The Swedish School of Sport and Health Sciences

Sweden

Madhusudhan Venkadesan

Yale University, Connecticut

United States

Michael Rainbow

Queen's University, Kingston

Canada

Cesar de Cesar Netto

University of Iowa, Iowa City-IA

United States

Irene Davis

Harvard Medical School, Cambridge

United States

CHAIR WOMEN

Profa. Isabel de Camargo Neves Sacco, Associate Professor in the Department of Physiotherapy, Speech Therapy and Occupational Therapy at the Medical School of the University of São Paulo (FMUSP) is the first woman to hold the position of president of the International Foot & Ankle Biomechanics Meeting (i-FAB), considered the largest congress on the subject in the world.

In addition, for the first time in the history of the Congress, the sessions of the event will be chaired mainly by women. Meet some of them below:

Isabel Sacco
Universidade de São Paulo

Chair of i-FAB 2021

Alessandra Bento Matias
Universidade de São Paulo

Oral session: Kinematics Methodological Aspects I

Amy L. Lenz
University of Utah

Oral session: Kinematics Methodological Aspects II

Ana Paula Simões
Hospital Santa Casa de São Paulo

Oral session: Orthopedics I (surgical aspects)

Andresa Germano
Chemnitz University of Technology

Oral session: Sports

Annamaria Guiotto
University of Padua

Oral session: Weight Bearing CT I

Anne Rasmussen
Steno Diabetes Center Copenhagen

Oral session: Diabetic foot I

Aoife Healy
Staffordshire University

Oral session: Clinical Biomechanics II

Carina Price
University of Salford

Oral session: Footwear/ Orthotics

Claire Brockett
University of Leeds

Oral session: Tissue Biomechanics

Claudia Giacomozzi
Italian National Institute of Health

Oral session: Diabetic foot II

Cylie Williams
Monash University

Oral session: Pediatrics

Deyse Borges Machado
UDESC

Oral session: Foot Biomechanics

Elizabeth Pedersen
University of Alberta Hospital

Oral session: Orthopedics I (surgical aspects)

Elyse Passmore
The Royal Children's Hospital and Murdoch Children's Research Institute

Oral session: Kinematics Methodological Aspects II

Eneida Yuri Suda
Universidade de São Paulo

Oral session: Chronic Ankle Instability

Erica Queiroz da Silva
Universidade de São Paulo

Oral session: Diabetic foot II

Fabiola Spolaor
University of Padova

Oral session: Foot-Ankle Modelling

Heiliane de Brito Fontana
Universidade Federal de Santa Catarina

Oral session: Tissue Biomechanics

Irene Davis
Harvard Medical School

Oral session: Kinematics Methodological Aspects I

Isabelle Van Dalen
Bergmanclinics

Oral session: Orthopedics II

Jayishni Maharaj
Griffith University

Oral session: Weight Bearing CT I

Julie Stebbins
Oxford University Hospitals

Oral session: Foot Biomechanics

Karine Jacon Sarro
UNICAMP - Universidade Estadual de Campinas

Oral session: Kinematics Methodological Aspects Iv

Kirsten Tulchin Francis
Texas Scottish Rite Hospital for Childrez

Oral session: Pediatrics

Lena Fennen
Westfälische Wilhelms-Universität Münster

Oral session: Clinical Biomechanics I

Liu Chiao Yi
Unifesp

Oral session: Sports

Mary K. Hastings
Washington University School of Medicine

Oral session: Diabetic foot I

Rajshree Hillstrom
Biomed Consulting, Inc.

Oral session: Weight Bearing CT II

Rosemary Dubbeldam
University of Muenster

Oral session: Clinical Biomechanics I

Ruth L. Chimenti
University of Iowa

Oral session: Orthopedics II

Sandra Aliberti
Universidade de São Paulo

Oral session: Chronic Ankle Instability

Sarah Ridge
BYU College of Life Sciences

Oral session: Running

Sharon Dixon
University of Exeter

Oral session: Footwear/ Orthotics

Sophie De Mits
Artevelde university of Applied Sciences

Oral session: Weight Bearing CT II

Thanaporn Tunprasert
University of Brighton

Oral session: Clinical Biomechanics II

Zimi Sawacha
University of Padova

Oral session: Foot-Ankle Modelling

SPECIAL
SESSIONS

DIABETIC FOOT

Date & Time: April 12, 2021 | 2:40 – 4:30pm (GMT-3)
Room: 1
Simultaneous translation available (EN-PT)
Chairs:

David G. Armstrong
Keck School of Medicine of University of Southern California
USA

Sicco Bus
University of Amsterdam,
Netherlands

WEIGHT-BEARING CT

Date & Time: April 14, 2021 | 10:55am – 12:45pm (GMT-3)
Time: **Room**: 1
Simultaneous translation available (EN-PT)
Chairs:

Francois Lintz
International WBCT Society
France

Alberto Leardini
Istituto Ortopedico Rizzoli, Bologna
Italy

ABSTRACT
AWARD

To encourage Scientists all over the world, i-FAB 2021 organizing committee has decided to award two best oral presentations, being at least one for a student.

The award will be presented during the closing ceremony of the i-FAB 2021, on April 14th, 2021 and the winners will be honored with full registration for the i-FAB 2023 Congress which will be held in France.

Each session will be judged by invited jury from our board consisting of distinguished scientist of the Biomechanics field. The choice of the jury will be based on scientific excellence and the presentation of the scientific information on the oral presentations, as well as the talk of the presenting author.

If the 2023 edition is in face-to-face format, the winners registrations will include: welcome reception and 3 days of congress with break and lunch.

BOOK OF ABSTRACTS

International FOOT & ANKLE Biomechanics Meeting 2021 ONLINE

2D versus 3D geometric analyses on bones and joints in weight-bearing and non-weight-bearing cone-beam CT images

Ruud H.H. Wellenberg[1,2*], Sara Berardo[3], Mark Broos[1], Johannes G.G. Dobbe[2], Mario Maas[1], Geert J. Streekstra[1,2]

[1] Department of Radiology and Nuclear Medicine, Amsterdam University Medical Center, location AMC, Amsterdam, The Netherlands
[2] Department of Biomedical Engineering and Physics, Amsterdam University Medical Center, location AMC, Amsterdam, The Netherlands
[3] Department of Radiology, University Hospital Maggiore della Carita, Novara, Italy
* r.h.wellenberg@amsterdamumc.nl

Introduction – Quantitative analyses on bones and joints are frequently performed to determine the status, stability and alignment of the foot [1]. The increasing use of weight-bearing (WB) CT urges the development of 3D analysis tools that deliver geometrical parameters corresponding to their well-known 2D counterparts. Since differences can be expected between 2D and 3D analyses, estimates of geometrical parameters were compared from WB and non-WB cone-beam CT and simulated radiographs.

Methods - WB and non-WB cone-beam CT-images of the left and right foot were acquired on a Planmed Verity cone-beam CT-scanner. Geometric analyses were performed on images of the foot in 2D using simulated radiography images and 3D using custom analysis software. Measurements included the calcaneal pitch, Meary's angle, angle between 1st and 2nd metatarsal (MTT), talo-calcaneal angle and cuboid height (Fig. 1).

Results - Currently, results of 5/20 patients are included. All measurement results were statistically different in 2D and 3D ($p<0.001$). Average calcaneal pitch decreased during WB in 2D and both 3D measurements. Meary's angle decreased in 2D measurements, however increased using 3D measurements. The average angle between MTT1-MTT2 increased in both approaches. During WB, the talocalcaneal angle decreased in both lateral-lateral and anterior-posterior 2D views and increased in 3D. Cuboid height decreased during WB in both 2D and 3D images ($p<0.001$).

Discussion - The geometric parameters evaluated in 2D were different compared to 3D, which is likely caused by over-projection and the specific point of view.

Relevance - We expect that 3D measurement tools are more univocal and therefore more suitable for future use. Also, switching to 3D enables advanced analysis such as obtaining joint space maps.

Reference

[1] Flores DV, Mejía Gómez C, Fernández Hernando M, Davis MA, Pathria MN. Adult Acquired Flatfoot Deformity: Anatomy, Biomechanics, Staging, and Imaging Findings. Radiographics. 2019 Sep-Oct;39(5):1437-1460

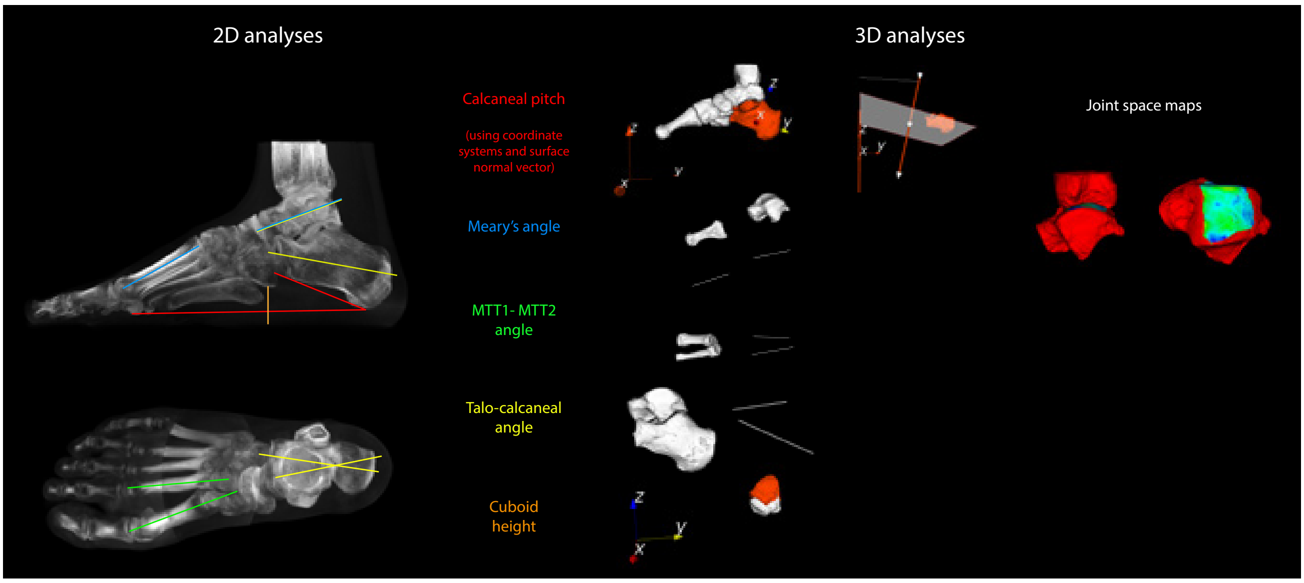


Figure 1: Overview of the 2D/3D measurements, which were performed on simulated radiography images and on segmented bones, obtained from weight-bearing and non-weight-bearing CT-images.

3D biometric weightbearing CT assessment of hindfoot alignment in adult aquired flatfoot deformity

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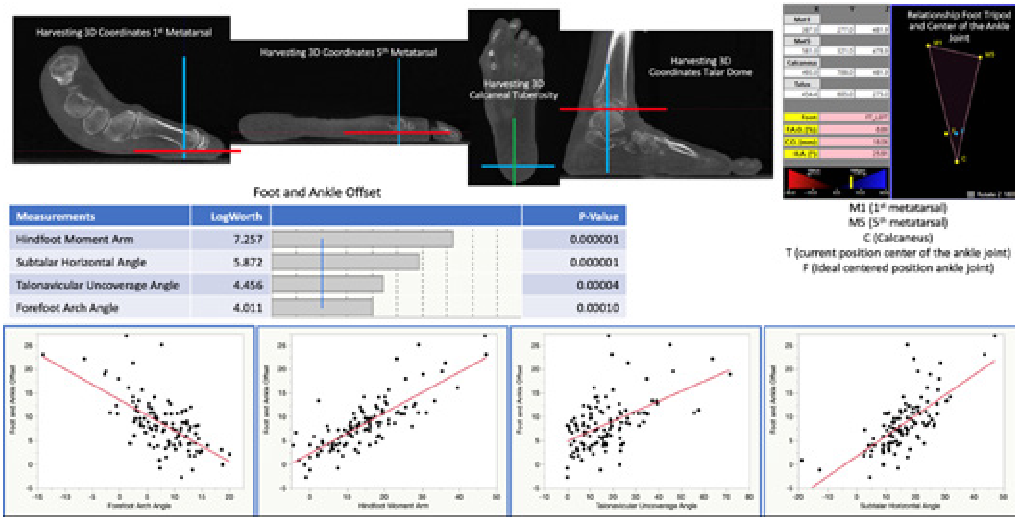
Introduction: Semi-automatic three-dimensional (3D) biometric weightbearing CT (WBCT) tools have been shown to accurately demonstrate the relationship between the center of the ankle joint and the tripod of the foot. The measurement of the Foot and Ankle Offset (FAO) represents an optimized biomechanical assessment of foot alignment. The objective of this study was to evaluate the correlation between FAO and traditional adult acquired flatfoot deformity (AAFD) markers, measured in different planes. We hypothesized that the FAO would significantly correlate with other radiographic markers of pronounced AAFD.

Methods: In this retrospective comparative study, we included 113 patients with stage II AAFD, 43 men and 70 women, mean age of 53.5 (range, 20 to 86) years. Three-dimensional coordinates (X, Y and Z planes) of the foot tripod (most plantar voxel of the first and fifth metatarsal heads, and calcaneal tuberosity) and the center of the ankle joint (most proximal and central voxel of the talar dome) were harvested by two blinded and independent fellowship-trained orthopedic foot and ankle surgeons. The FAO was automatically calculated using the 3D coordinates by dedicated software. Multiple WBCT parameters related to the severity of the deformity in the coronal, sagittal, and transverse plane were manually measured.

Results: We found overall good to excellent intra (range, 0.84-0.99) and interobserver reliability (range, 0.71-0.96) for manual AAFD measurements. FAO semi-automatic measurements demonstrated excellent intra (0.99) and interobserver reliabilities (0.98). Hindfoot moment arm ($p<0.00001$), subtalar horizontal angle ($p<0.00001$), talonavicular uncoverage angle ($p=0.00004$) and forefoot arch angle ($p=0.0001$) were the only variables found to significantly influence and correlate with FAO measurements, with an R-squared value of 0.79. A value of hindfoot moment arm of 19.8mm was found to be a strong threshold predictor of increased values of FAO, with mean values of FAO of 6.5 when the HMA was lower than 19.8mm and 14.6 when the HMA was equal or higher than 19.8mm.

Discussion: We found that 3D WBCT semi-automatic measurements of FAO significantly correlated with traditional markers of pronounced AAFD. Measurements of FAO were also found to be more reliable than the manual measurements.
Relevance: The FAO offers a more complete biomechanical and multiplanar assessment of the AAFD, representing in a single measurement the three-dimensional components of the deformity.

Figure 1. Correlation between three-dimensional biometric weight-bearing CT assessment of hindfoot alignment and traditional measurements of adult acquired flatfoot deformity.



3D joint space width from weight bearing CT detects progressive narrowing after tibial pilon fractures

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Introduction: Post-traumatic osteoarthritis (PTOA) affects over 50% of patients with tibial pilon fractures [1]. Clinical scales like the KL grade are used to assess arthritic changes from plain radiographs, but they are subjective and lack sensitivity needed for early PTOA monitoring [2]. The lack of reliable early indicators of PTOA impedes the development of preventative strategies. Weight bearing CT (WBCT) enables 3D assessment of the ankle in a functional pose. This study evaluated longitudinal changes in the tibiotalar 3D joint space width (JSW) from 6 to 12 months after pilon fractures.

Methods: Sixteen patients with tibial pilon fractures were enrolled at 3 institutions in this IRB-approved study. Patients returned at 6 and 12 months after fracture fixation for WBCT scans. Using a semi-automated segmentation technique, 3D triangulated meshes were generated for the tibia and talus. Longitudinal scan data and meshes were aligned in 3D Slicer based on CT image intensities of the talus. JSW measurements were analyzed using the aligned 6-month talus as a common datum (Figure 1). The change in 3D JSW (ΔJSW) was measured for the 16 fractured ankles, as well as for 10 intact ankles, to assess measurement reliability.

Results: Some, but not all, fractured ankles showed joint space narrowing. The ΔJSW in the fractured ankles was -0.25 ± 0.20 mm, compared to -0.03 ± 0.13 mm in the intact ankles, indicating an overall narrowing in the joint space. We found differences in ΔJSW consistent with clinical experience that the speed and quantity of cartilage loss varies between fractures (Figure 2). The five fractures with the most JSW change (Group 3) averaged a 0.49 ± 0.07 mm decrease in JSW. The ΔJSW values for the group with the least ΔJSW (Group 1) were indistinguishable from intact ankles. For Group 3, an average 48% of the articular surface saw a decrease exceeding 0.5mm, with 14% of the surface decreasing more than 1 mm.

Discussion: These findings indicate that WBCT scans of the tibiotalar joint can be used to detect early changes in 3D JSW after tibial pilon fracture. The early changes may be associated with progressive joint degeneration, but further evaluation will be required before drawing this conclusion.

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Acknowledgements: This work was partially funded by a grant from the Orthopaedic Trauma Association.

Figure 1. Changes in 3D JSW from 6 to 12 months show early joint space narrowing on the fractured side.

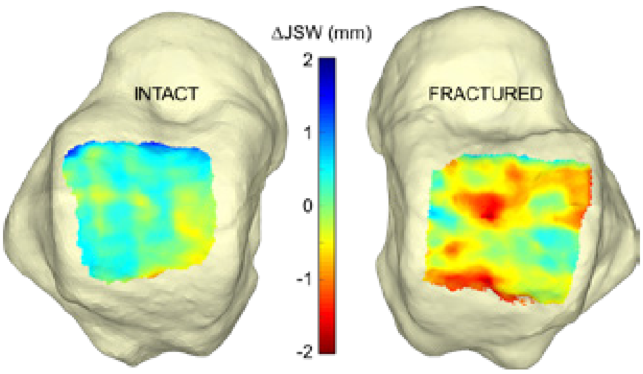
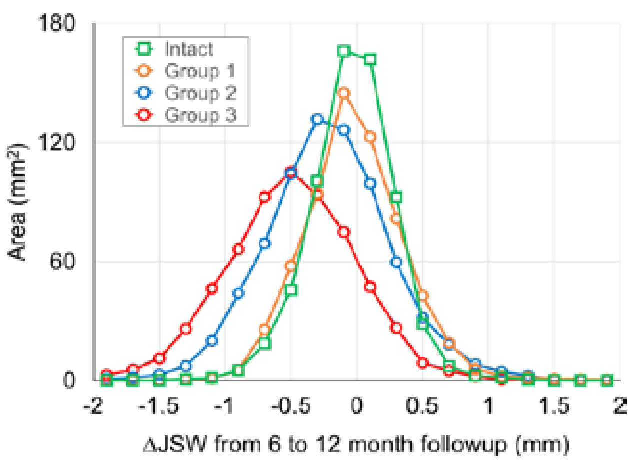


Figure 2. The average areas of the articular surface with changes in JSW indicate substantial narrowing for some but not all ankles.



3D measurements of bone alignments in weight-bearing for quantitative clinical assessments of foot skeletal architecture

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The foot architecture is very complex, to be able to respond to load and to push in elevation and progression of the body by the loading conditions [1]. Traditional X-ray based measurements are limited by the projection in a single plane [2], and standard CT are in supine, in non weight bearing. Angular measurements depends on subjective identification of anatomical landmarks or alleged longitudinal axes. Modern weightbearing CT devices based on cone-beam tomography (CBCT) today allow objective quantification of the foot skeletal posture in 3D in different loading conditions, e.g. in single or double leg upright postures in weight-bearing [3,4]. New techniques are now available for automatic or semi-automatic measurements of 3D position and orientation of foot and ankle segments from CBCT scans [5]. These methods have been developed and exploited in our Institute for a number of different studies [6-8].

Basically, DICOM files of the CBCT scans ('OnSight 3D Extremity System', Carestream, Rochester, NY) of the foot are segmented using a large number of manual or automatic software tools, to define corresponding 3D models of each bone in STL format for any further analysis. A global anatomical reference frame must be established for the entire foot. Local, i.e. for each bone, anatomical reference frame should be defined, by using geometrical algorithms or the Principal Component Analysis (PCA). Absolute and relative orientations between bones, in 3D and in 2D projections in any of the three anatomical planes, distances and dimensions, can then be easily calculated [5,6].

The present technique is now applied for objective automatic measurements of foot bone alignments in a number of patients with foot alterations, such as diabetic foot, pre- and post-op flat foot, hallux valgus and severe ankle arthritis.

The new technique allows multi-planar measurements using complete 3D models of the foot bones and has revealed to be more repeatable and more anatomically accurate than standard X-ray based measurements, also removing the artefacts associated to foot positioning and deformity [5]. While segmentation of bones is still a semi-automatic time-consuming procedure, the automatic definition of landmarks, axes and reference frames removes any subjective variability and bias from the analysis of foot bone architecture, which can now be investigated in 3D and in different weight-bearing conditions, thus opening the door to a number of new biomechanical and clinical investigations [2-8]. New automatic segmentation tools shall facilitate soon the introduction of these techniques also in routine clinical analyses.

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3D Weight-Bearing Bone Architecture Measures to Enhance Plantar Loading Analysis in the Diabetic Foot

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Introduction. Knowledge and prevention of diabetic foot ulceration process may benefit from the integration of plantar loading and human motion analyses [1], but most recently also from 3D measures of bone alignment from weightbearing cone-beam computer tomography (CBCT) [2]. The present study investigates correlations between 3D bone alignment (3D), dynamic plantar loading (LOAD), functional (FUNC), biological (BIOL) and clinical (CLIN) variables in patients with type-1 Diabetes.

Methods. Dicom files were obtained from CBCT scans (OnSight 3D Extremity, Carestream, US) of the most compromised foot from 15 type-1 Diabetic patients - 8 without (D) and 7 with (N) neuropathy - and 1 LADA (L). After segmentation, the 3D models of the bones were processed (Matlab 2017b) to perform automatic geometrical calculations based on either anatomical landmarks and axes, or on the Principal Component Analysis. For the joints, planar angles in all three anatomical planes and in 3D were calculated. Pressure patterns were acquired (EMED q-100), registered and averaged over 5 consistent gait trials for each patient and foot.
Parameters. 3D: metatarsal (M1-5) and phalanx (P1-5) bones were analyzed, for their height from the floor (H), absolute (I) and relative (R) orientations, i.e. phalanx-to-metatarsal, in the sagittal (L) and transverse (T) planes and in the 3D space (3), for a total of 65 parameters; LOAD: Peak Pressure (PP), Pressure-Time Integral (PTI) and PTI normalized to contact time (NPTI) were calculated at hallux and at first (M1), central (MC) and fifth (M5) metatarsals, for a total of 12 parameters; FUNC: contact time (CT) and arch index (AI) collected during and averaged over the gait trials; BIOL: age and BMI; CLIN: duration of disease and a combined neuropathy-related score (CNS).

Results. Weak-to-moderate significant correlations ($p<0.05$, R^2 range 0.25-0.60) were found between 3D and the other groups of parameters (worth to mention, R^2=0.60 between IL_P1 and AI). Peculiar, moderate-to-strong correlations ($p<0.05$, R^2 range 0.56-0.90) were found in D and N separately. Some of these correlations may help understanding the cause for increased forefoot loading, such as the very strong positive correlation (0.90) between I3_P3 and NPTI at MC in the neuropathic group (Fig 1B); some others revealed peculiar links of 3D to FUNC, BIOL and CLIN, such as the strong negative correlation (0.78) between Hg_M1 and CT in the non-neuropathic group (Fig 1C).

Figure 1: (A) Foot model registered on the corresponding pressure map, from a representative patient; (B) correlation between 3D inclination of 3rd phalanx (I3_P3) and normalized pressure-time integral at central metatarsals (NPTI_MC); (C) correlation between height of the 1st metatarsal (Hg_M1) and contact time (CT)

Discussion&Relevance. Despite its complexity, the integration of consolidated foot loading analysis with this novel technique for the 3D investigation of foot bone architecture while bearing weight seems to bring a much valuable contribution to Diabetic foot biomechanics.

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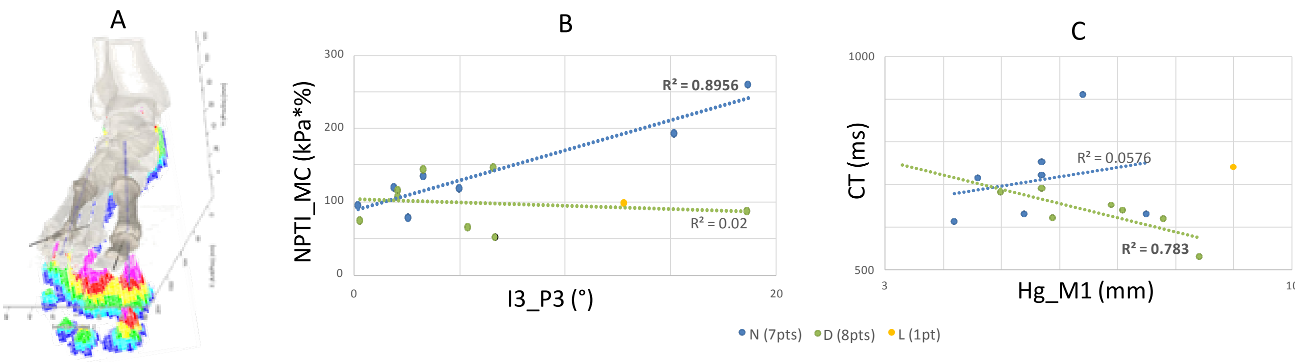

A comparison of a multi-segment foot model to a one-segment foot model during balance tasks

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Background: In balance research, the hip and ankle joints have been of special interest [1]. The ankle joint is defined as the connection between the tibia and the foot, where the foot has been represented as one segment. However, the foot should be inspected more, because it forms the base of support [2]. The interaction of its many segments is specific to humankind [3]. Therefore, investigations using multi-segment kinematic foot models may increase insights into the role of individual foot structures during balance tasks [4]. It was hypothesized, that the foot segments demonstrate a higher level of motion during tasks with increasing balance difficulty.

Methods: The movement of 11 participants without any impairments (age: M = 23.18 years) was recorded with Qualisys and further processed with Visual3D. Five foot segments were defined by 21 markers per foot in accordance to the Ghent Foot Model (GFM) [4]. Four balance tasks with increasing difficulty levels were performed and compared: two-limb stance, two-limb stance with eyes closed, one-limb stance and one-limb stance with eyes closed. Foot and ankle segment angles between tibia and rearfoot (RF_Tibia), rearfoot and midfoot (MF_RF), midfoot and medial forefoot (MFF_MF) and midfoot and lateral forefoot (LFF_MF) were calculated in the GFM [3]. In addition, the angle between the tibia and the one-segment foot (Ankle_Angle) was calculated. The segment's amount of motion during the balancing tasks was presented by the cumulative range of motion (cumROM). Repeated measure 3 (Axes) x 4 (Conditions) factorial ANOVAs were used to analyze the foot segment angles separately with a significant level set at α = .05. Bonferroni multi-measurement corrections were applied.

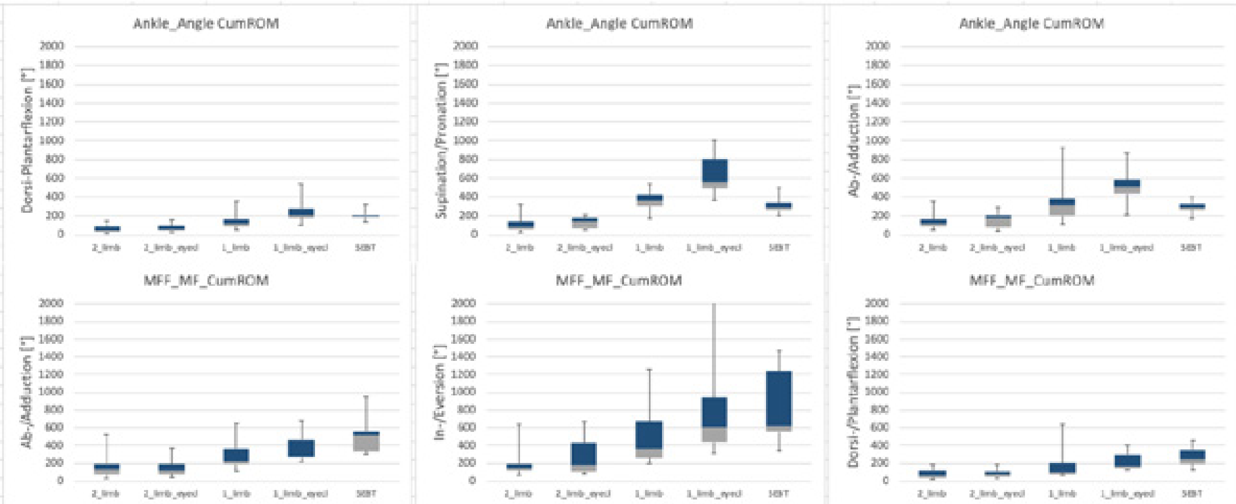
Results: There was a statistically significant increase in foot segment joint angle motion with increased balance task difficulty (Table 1). From Figure 1 it becomes clear, that the foot segment's cumROM reached higher values than those of the ankle joint. Moreover, MFF_MF and LFF_MF showed the highest values. Further, the cumROM motion of the foot segments reached similar and larger values than those of the ankle.

Conclusion: The present findings support the hypothesis, that the foot segment's motions increase with increased balance difficulty. This indicated that the individual foot segments may be involved in balance maintenance. A further investigation of the relationship between foot and ankle impairments and the corresponding influences on the contribution of the foot in balance tasks is of interest.

Table 1. Result of repeated-measure factorial 3 (Axes) x 4 (Conditions) ANOVA.

Of Conditions	RF_Tibia	MF_RF	LFF_MF	MFF_MF	Ankle_Angle
F value	(1.575, 15.746) = 41.576	(3, 30) = 33.412	(1.184, 11.836) = 6.781	(1.232, 15.354) = 31.331	(1.488,14.882) =5 4.579
P value	< .001	< .001	< .001	< .001	< .001

Figure 1. Example cumROM of the ankle joint and the MFF_MF joint in anatomical planes.



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A Multi-segment Foot Model for Detailed Kinematics and Kinetics Analysis

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This study aimed to create a novel multi-segment foot model to analyze not only the foot kinematics but also the kinetics during dynamic movements. To evaluate whether it can be applied to dynamic foot movements, we analyzed a drop-jump motion using the model.

This foot model had three segments: phalanx, forefoot, and hindfoot (Figure 1A). Mass, center of mass, and moment of inertia of each segment were calculated based on the CT data of the foot from one healthy male subject (42 years old, 72 kg, 172 cm) using CAD software (Figure 1B). The model was scaled by the cube root of the segment mass to create a subject-specific foot model.

Ten healthy men performed drop-jumps. The participants were asked to land on the front and rear force plates by their fore- and hindfoot, respectively (Figure 1C). The joint angles were described by y-x-z Euler angles, representing dorsi-/plantar-flexion (Do/Pl), eversion/inversion (Eve/Inv), and abduction/adduction (Abd/Add), respectively. The joint moments were calculated by inverse dynamics analysis based on the Newton-Euler method.

A pattern of foot motion was confirmed to be similar to that of our previous study [1] (Figure 2). This model was able to estimate and evaluate 3D motions and moments within the foot segment which cannot be detected by a model that treats the foot as a single rigid body.

The proposed novel model may be useful for a detailed analysis of kinematics and kinetics of the foot during dynamic movements.

Figure 2. The joint angles and moments for the right foot contact phase are shown.

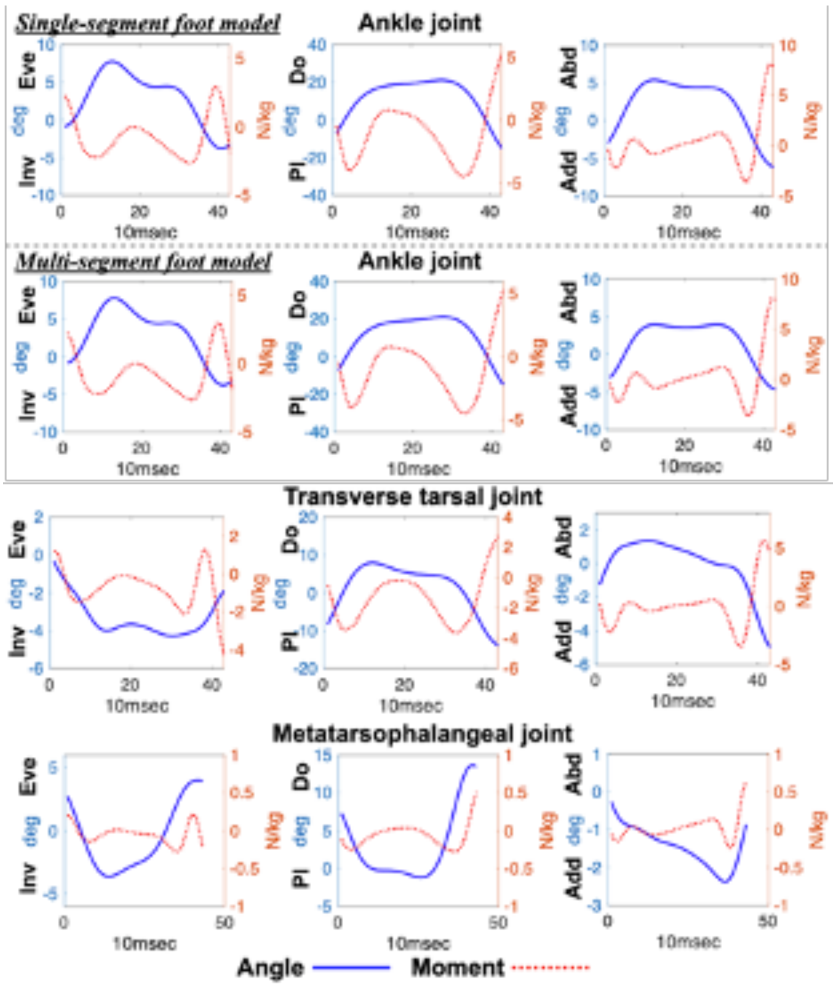
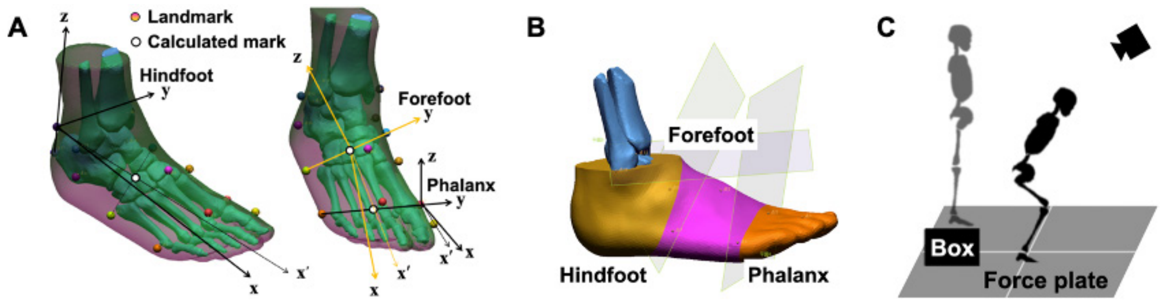


Figure 1. (A) The proposed foot model; (B) The segmented foot based on the CT data; (C) The brief illustration of measurement scene



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A preliminary analysis of plantar pressure data in infants at the onset of walking and confidently walking using pedobarographic statistical parametric mapping (pSPM)

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Introduction: Plantar pressure data has been investigated in new and confident walkers through regional analysis [1]. This however is a low-resolution approach to pressure data and makes underlying assumptions regarding the independence of functionally significant foot regions [2]. Therefore, this study aims to compare plantar pressure patterns between new and confident walkers through the use of pedobarographic statistical parametric mapping (pSPM).

Methods: A sample of 11 infants were tested within 3 weeks of taking 3 to 5 independent steps, and when they could walk confidently. At both milestones, infants walked freely across an EMED-xl pressure platform (Novel GMBH, Munich, Germany sampling at 100Hz). Ten steps per infants, per foot, at each milestone were extracted and imported into MATLAB 2019a (Mathworks, Natick, USA) for the analysis. Pixel images were transformed to point clouds and between-subjects registration was performed using a non-linear, rigid, affine body transformation [3]. Point clouds were also averaged within-subjects, in order to have one mean image per foot, per subject at each milestone. Pressure patterns were compared between new and confident walkers using nonparametric paired sample SPM1D t-test [4].

Results: There were no statistically significant differences between the two infants' groups for the left ($t=\pm5.27$; $p\geq0.05$) and right foot ($t=\pm4.88$; $p\geq0.05$) (Figure 1).

Discussion: As opposed to previous results with regional analysis, the pSPM approach within this work highlighted the absence of significant differences in plantar pressure patterns between new and confident walkers.

Relevance: This study used, for the first time, pSPM to analyse pressure data in infancy. However, further work is warranted to establish the optimal sample size to capture statistically significant changes in pressure patterns between new and confident walkers using pSPM.

Keywords: pSPM, infants, gait

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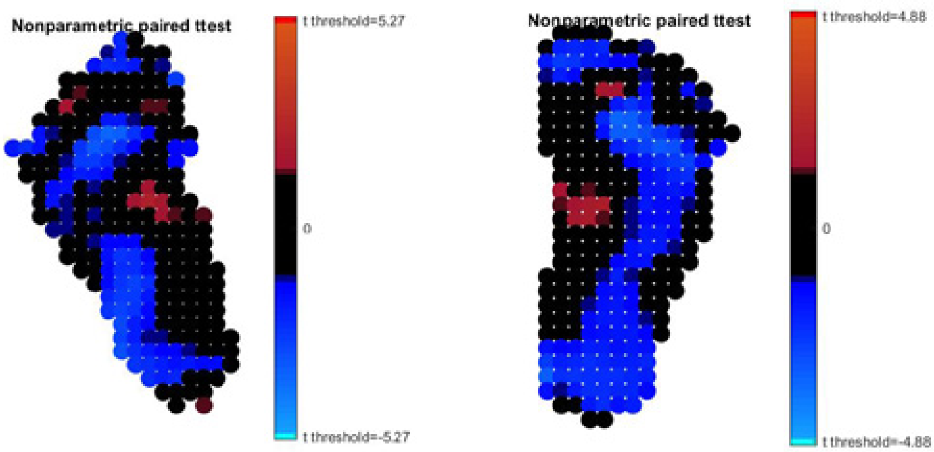
Figure 1. *pSPM analysis. Positive (red) and negative (light blue) t threshold values are indicated next to the colour bars of each set of point clouds. Although significant differences were not found, blue and magenta coloured points indicate clusters that were subject to increasing (blue clusters) and decreasing (magenta clusters) pressure in confident walkers.*



Acceleration of the centre of mass of the body increases heel fat pad deformation and energy absorption

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Introduction

The heel pad is a fibroadipose, viscoelastic tissue inferior to the calcaneus. It has a complex, three-dimensional structure that makes it challenging to measure its *in vivo* deformation with high accuracy. The heel pad attenuates the shock of impact, which is important as impact transients have been linked to injury [1]. Impact transients in running are affected by acceleration of the centre-of-mass (COM) however, the fat pad's response remains unclear. Here, we investigate how the acceleration of the COM changes foot bone velocity, and consequently heel pad energy absorption, using a novel approach derived from biplanar videoradiography.

Methods

One subject (M/51Y/83kg) with tantalum beads embedded in the calcaneus ran barefoot overground at a consistently slow pace (2.63±0.03 m/s), with COM accelerations of 14.5(D), 7.8(LA), and 11.4(FA) m/s^2. He ran over adjacent force plates (AMTI), such that the ground reaction forces under the hindfoot and forefoot were isolated while biplanar x-ray was captured (250 Hz). Custom software (XMALab) tracked the position of the beads to determine the movement of the calcaneus. Three-dimensional models of the calcaneus and the unloaded heel pad were created from a CT scan (0.391x0.391x0.625mm). The perpendicular distance from the calcaneus to a grid placed on the precisely located floor simulated the heel pad deformation. The unloaded heel pad determined the average resting length over the grid. Energy absorption during loading was the integral of the vertical ground reaction force vs. fat pad displacement.

Results & Discussion

As COM accelerations increased, the absorbed energy increased substantially (D:1.05J/LA:2.7J/FA:9.7J), the heel pad deformed more (D:7.64mm/LA:8.5mm/HA:10.1mm), and the initial contact velocity of the calcaneus was higher (D:0.99/LA:1.19/FA:1.36 m/s) despite the same velocity of the calcaneus at toe-off. The force of impact however was lower with increased COM acceleration (D:1365N/LA:1275N/HA:1237N). Inconsistent with the literature, this reduced the quasi-stiffness of the heel pad. Our approach however, detected different areas of heel pad contact in each condition, which incorporates heel pad shear forces into the vertical measurement. This suggests that the ankle angle, which changes as a result of acceleration [2], can change the direction of loading of the fat pad, as the lateral direction of the fat pad is more compliant [3].

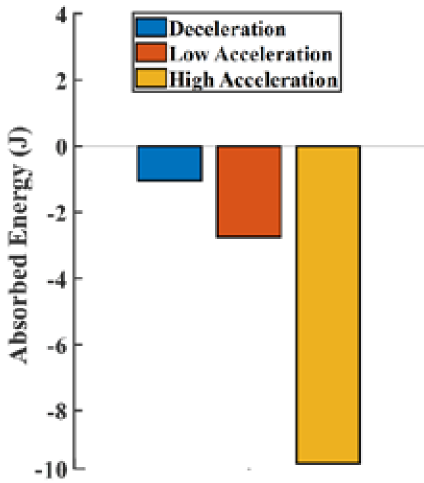

Figure 1. Absorbed energy in the fat pad of the heel during overground running while the centre of mass of the body moves at a near-constant velocity, while decelerating, accelerating slowly, and accelerating quickly.

Conclusion

Despite near-constant COM velocities, increases in COM acceleration corresponded with increases in calcaneus initial contact velocity and energy absorption at the heel pad. It is likely that the stiffness of the fat pad differs depending on ground contact point.

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Accuracy and reliability of skin-markers based measures of the medial longitudinal arch of the foot

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Background
The medial-longitudinal arch (MLA) of the foot is one of the most important features characterizing foot morphology. While the importance of measuring the foot MLA is widely recognized, no consensus has been reached on which MLA model used in motion analysis is better representing the real MLA posture and deformation. The aim of this study was to propose novel MLA measures based on skin-markers and assess their accuracy and repeatability with respect to current X-ray based measures.

Methods
Four geometrical definitions of MLA angle (MLA1-MLA4), and four variations (MLA1b-MLA4b) were devised according to skin-markers located on the calcaneus (CA), sustentaculum tali (ST), talo-navicular tuberosity (TN), the two malleoli and head (FMH) and base (FMB) of the first metatarsal bone (figure 1, left). These MLA definitions aimed at replicating the clinical

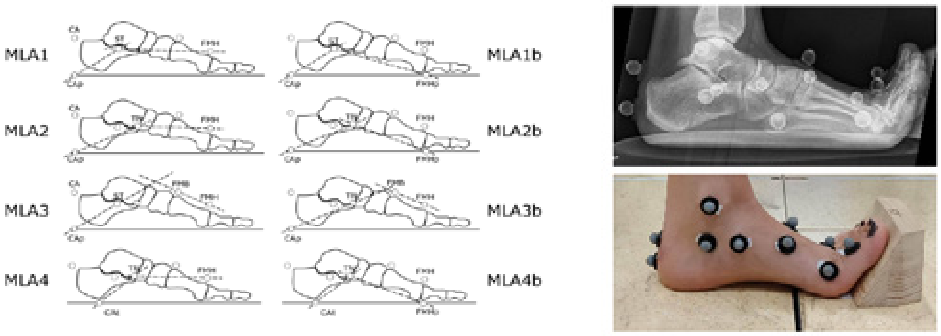

Figure 1. Left, skin-markers based definitions of MLA angle. Right, a wooden wedge is used to bring about maximum MLA rise for each subject.

Moreau-Costa-Bertani angle [1] and the angle between rearfoot and first metatarsal inclination [2]. The eight MLA measures were implemented in Visual3D (C-Motion, Kingston, ON) as angles between two 3-dimensional vectors bounded by pairs of markers, and as planar angles after projecting the vectors on the sagittal plane of the foot, for a total of sixteen definitions. Accuracy of the models in measuring MLA deformation was assessed against radiography-based MLA measurements (figure 1, right) in 12 subjects (age 27 – 75 years; BMI 17 – 28.7 kg/m^2). Repeatability was assessed via analysis of the average standard deviation error across a number of walking and running trials, which were pooled as established in [3].

Results
The highest accuracy was found for MLA4 (error = 3.3 ± 3.5 deg; $p < 0.05$) and the lowest for MLA1b (error = 23.8 ± 10.2 deg; $p < 0.05$). MLA measurements showed similar variability in walking and running. The inter-trial variability was lower than 1.0 deg, the inter-session in the range 2.9 – 7.7 deg, and the inter-examiner in the range 3.7 – 9.3 deg, across all MLA definitions. The sagittal-plane projections showed larger variability than the corresponding MLA measures and, in general, larger variability was detected for MLA definitions based on larger number of markers (e.g. MLA3 and MLA3b).

Conclusions
According to the results of the present investigation, skin-markers based measures of the MLA established on minimal marker-sets, and calculated as 3-dimensional angles, are recommended to improve repeatability. Better accuracy with respect to standard radiological measures can be obtained by tracking the MLA shape using markers on the calcaneus tubercle, the talo-navicular apex and the head of the first metatarsal bone.

Acknowledgments
This study was supported by the Brazilian National Council for Scientific and Technological Development (CNPq # 305606/2014-0), and by the **São Paulo Research Foundation (FAPESP #**2017/23975-8).

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Adaptative strategies to reduced ankle dorsiflexion range of motion

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Introduction

During gait, ankle dorsiflexion range of motion (ADF-ROM) contributes to forward movement of the body. Reduce ADF-ROM, usually due to plantar flexors lower extensibility [1], may alter movement patterns in order to compensate or adapt the limited anterior tibia roll over the foot. Based on biomechanical reasoning, excessive foot pronation might complement an inefficient dorsiflexion at the ankle joint [2]. In other way, individuals with reduced ADF-ROM might take advantage to their lower extensibility to increase their lower limb global stiffness and explore more of their passive properties to move the body forward [3]. Therefore, this study investigated the adaptative strategies to reduced ADF-ROM, rather excessive foot pronation or increase lower limb global stiffness during walking at a self-selected speed.

Methods

Sample: Thirty-two participants, allocated in two groups according to passive ADF-ROM (less than 10° and greater than 15°) participated in this cross-sectional observational study (CAAE 84029718.6.0000.5149).
Inclusion criteria: (1) age between 19 and 44 years old; (2) no injury or surgery in the lower limbs or pelvis in the last six months; (3) shank-forefoot alignment angle smaller than 14°; (4) hip internal and external rotation ROM between 34 and 71°, and 25 and 56°, respectively, for women, and between 23 and 53°, and 29 and 56°, respectively, for men.
Exclusion criteria: Complaints of pain or discomfort during data collection.
Procedures: Clinical ADF-ROM was assessed using a goniometer, with the participant in prone with the knee extended. Kinematic data during self-selected walking speed were collected with a tridimensional motion analysis system.
Data reduction: The peaks of forefoot-rearfoot dorsiflexion and rearfoot-shank eversion and abduction of the dominant lower limb were analyzed. The lower limb global stiffness (kb^2) of stance phase was calculated using the inverted pendulum model equation [4]: $kb^2=(mL^2/(\tau/2\pi)^2)+mLg$.
Data analysis: Independent t-tests were used to compare the foot pronation movements and kb^2 between groups, considering α= 0.05.

Table 1: Lower and higher passive ADF-ROM groups descriptive and statistical data of the variables analyzed.

Variables	< ADF-ROM Mean (SD)	> ADF-ROM Mean (SD)	Mean difference (95% CI)	p	Effect size (d)
Passive ADF-ROM (°)	6.63 (1.89)	19.04 (3.23)	12.4 (10.5 – 14.3)	<0.001*	4.77
Peak of forefoot-rearfoot dorsiflexion (°)	12.22 (2.41)	16.77 (3.98)	4.54 (2.2 – 6.9)	<0.001*	1.41
Peak of rearfoot-shank eversion (°)	1.75 (2.84)	1.06 (2.93)	0.01 (-1.9 – 1.9)	0.99	0.24
Peak of rearfoot-shank abduction (°)	5.71 (2.5)	4.42 (2.13)	-1.29 (-3.0 – 0.42)	0.13	0.56
Kb^2 (Nm)	743.8 (204.8)	542.0 (107.2)	-201.9 (-322.4 - -81.4)	0.002*	1.23

Results

The lower passive ADF-ROM group (n = 17) presented significantly lower passive ADF-ROM ($p < 0.001$) and higher kb^2 ($p = 0.002$). In addition, no difference was found between groups regarding the peaks of forefoot-rearfoot dorsiflexion and rearfoot-shank eversion and abduction (Table 1).

Conclusions

Individuals with reduced ADF-ROM seems to take advantage of the grater lower limb stiffness, exploring more the tissues elastic properties, caused by the lower extensibility of the plantar flexors. Excessive foot pronation was not observed in the lower passive ADF-ROM group. In fact, individuals with reduced ADF-ROM presented lower forefoot-rearfoot dorsiflexion. The emerging movement patterns is the best solution of the system to accomplish the task (REF). Therefore, adapt to the available resources appears to be a more efficient gait pattern than compensate with additional movements thru excessive foot pronation.

Acknowledgments: CAPES, FAPEMIG, and CNPq.

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Alignment of the ankle and subtalar joint in normal bilateral standing

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INTRODUCTION

Various pathologies of the foot and ankle, including arthritis, chronic instability, and varus and valgus deformities, affect the alignment between the articulating bones of the ankle joint. Measuring this misalignment is important for diagnosis and quantification of the deformity for surgical correction. Several measures of misalignment have been previously established, such as the Saltzman angle [1], but most of these measures rely on two-dimensional x-ray measurements. Others, such as the Foot Ankle Offset parameter [2] provide a measure of overall foot and ankle alignment and foot classification but are not specific to individual joint and do not provide a full description in six degrees of freedom. It is therefore desirable to define misalignment of the hindfoot based on the three-dimensional position between the articulating bones using weight bearing CT. To this end, the goal of this study was to provide a database to establish the normal, neutral, bi-lateral weight bearing hindfoot alignment.

METHODOLOGY

Fifty normal subjects were recruited for this study, and weight bearing CT scans were collected (CurveBeam™) in bi-lateral neutral standing. The CT images were then processed via segmentation and 3D rendering (MIMICS™ and GEOMAGIC™). Tibial, talar, and calcaneal reference frames were defined for each bone based on its specific anatomy following, to the most part, biomechanical and orthopedic conventions [Fig 1]. Using these reference frames, the relative positions between the articulating bones at the tibiotalar joint (tibia and talus), subtalar (talus and calcaneus), and ankle joint complex (tibia and calcaneus) were defined [Fig 1] following the Grood and Suntay convention [3]. Using these definitions, three positional and three orientation parameters were calculated for each subject.

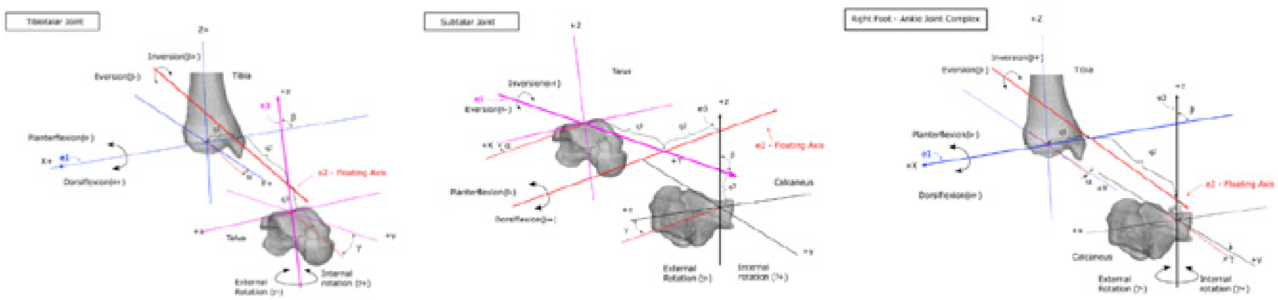

Figure 1: Grood and Suntay parameters [3] relating the Tibiotalar, Subtalar, and Ankle Joint Complex

RESULTS

Average, minimum, maximum, and standard deviation for the three orientation (Table 1) and position (Table 2) parameters between the bones at each joint were calculated and tabulated.

	Tibiotalar Angles (degrees)			Ankle Joint Complex Angles (degrees)			Subtalar Angles (degrees)		
	e1 (α)	**e2** (β)	**e3** (γ)	**e1** (α)	**e2** (β)	**e3** (γ)	**e1** (α)	**e2** (β)	**e3** (γ)
Max	10.06	94.69	18.54	8.38	98.19	12.09	17.18	95.61	12.03
Avg	0.45	87.59	1.53	-0.39	93.35	0.71	3.53	89.72	-1.74
Min	-5.64	74.88	-23.83	-7.81	87.10	-15.12	-6.99	82.04	-16.80
STDEV	3.04	4.23	7.04	3.37	2.05	6.01	6.44	2.65	7.38

Table 1: Rotational Parameters for Tibiotalar (Tibia to Talus), Ankle Joint Complex (Tibia to Calcaneus), and Subtalar (Talus to Calcaneus). These parameters are dorsiflexion/plantarflexion (α), inversion/eversion (β), and internal/external rotation (γ).

	Tibiotalar Translation (MM)			Ankle Joint Complex Translation (MM)			Subtalar Translation (MM)		
	e1 (q1)	e2 (q2)	e3 (q3)	e1 (q1)	e2 (q2)	e3 (q3)	e1 (q1)	e2 (q2)	e3 (q3)
Max	6.81	9.43	-0.15	8.59	13.33	-22.83	16.40	13.11	-18.07
Avg	-0.36	1.09	-1.82	-0.38	3.52	-31.62	4.59	0.19	-28.02
Min	-5.71	-2.30	-4.95	-10.88	-4.73	-39.46	-3.54	-11.02	-38.74
STDEV	2.17	1.92	0.90	3.63	4.68	3.87	4.13	4.38	5.14

Table 2: Translational Parameters for Tibiotalar (Tibia to Talus), Ankle Joint Complex (Tibia to Calcaneus), and Subtalar (Talus to Calcaneus). These parameters are medial/lateral (q1), anterior/posterior (q2), and proximal/distal (q3) translation.

DISCUSSION

A database for normal hindfoot alignment that can serve as the basis for comparison to determine misalignment in different foot and ankle pathologies has been developed. These results have clinical application to corrective surgery, allowing a surgeon to examine and quantify the degree of deformity present in comparison to the above values, as well as to determine the necessary rotation and translation of the bones to restore normal alignment. This gives the surgeon a quantitative tool to assist in the pre-surgical planning phase, as well as during the surgery itself.

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Analysis of intra-examiner reproducibility in the analysis of 2d ankle kinematics

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Considering biomechanics assessments excellent reproducibility is expected for analysis performed on different days and by different examiners. Reproducibility is especially important considering the analysis of angular kinematics performed using free software and often requiring manual actions from the examiner, for example, to identify the local of anatomical references to draw lines and angles. In this study, we determine the intra-examiner reproducibility of 2D ankle angular kinematics during treadmill running. Participants were 10 men (mean ± standard deviation age 45±11 years old, body mass 70±9 kg, height 166±0.71 cm). They are competitive pace (average speed of 12.6 km/h) on a motorized treadmill (Biodex, USA) with 1% of inclination. The 2D kinematic data were collected in the sagittal plane when the first kilometer of running was completed. Images were recorded at 30 Hz and post-processed to reach 60 Hz using a digital camera (Panasonic, Japan) placed 90 cm high at the side of the treadmill with the lens parallel to the plane of motion and 3 m far from the participant. Reflexive markers with 20 mm diameter were placed at anatomical references of the fifth metatarsal, lateral malleolus, and lateral epicondyle of fibula from the left side of participant's body. Ten strides were recorded for each participant and the sagittal ankle angles were determined at the foot strike. Three examiners of a similar level of expertise analyzed the videos on two different occasions separated by one week. Angles were determined using Kinovea version 0.0.3. The intra-examiner reproducibility as determined by the intraclass correlation (ICC) test was classified as weak (<0.40), moderate (0.40-0.75), and excellent (>0.75). Examiner 1 showed an ICC of 0.92, examiner 2 an ICC of 0.95, and examiner 3 an ICC of 0.93 (P<0.05). The overall ICC was 0.95 (P<0.05). All ICC values were classified as excellent. Therefore, we conclude that the analysis of 2D sagittal ankle kinematics during running shows excellent intra-examiner reproducibility allowing a comparison of the results obtained from different examiners in different days of video-analysis. We consider that a clear definition of the foot strike in the video analysis played an important role in the quality of results.

Analysis of the arch index in 13 to 19 years adolescents

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Introduction: The Medial Longitudinal Arch (MLA) can vary throughout life and several factors interfere in its development, which can impact on its absorption function and the movement economy[1]. The aim of this study was to analyze the characteristics of the Arch Index (AI) in adolescents aged 13 to 19.

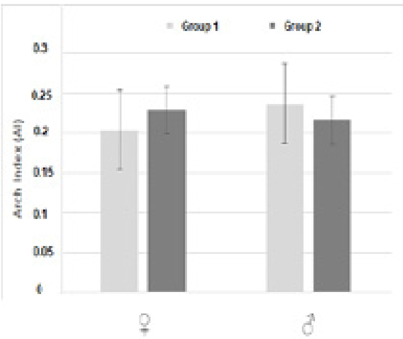
Methods: Thirty-nine adolescents of both sexes participated in this study, distributed into two groups: Group 1: 12 girls and 5 boys, aged 13 to 15 years; Group 2: 14 girls and 8 boys, aged 16 to 19 years. Footprints of both feet were recorded using a pedograph. The total foot area was determined and divided into three parts. The AI was calculated as the ratio between midfoot area (B) and total foot area (A + B + C), excluding fingers: AI = B / (A + B + C). The following classifications were adopted: High Arch (IAP ≤ 0.21); Normal Arch (0.21 <IAP <0.26); Low Arch (IAP ≥ 0.26) [2].

Results: There were no significant differences in AI values between different ages groups, but their classification were different: the youngest girls presented high arch, and the other participants presented normal arch.

Discussion: In adolescence, MLA changes seem to stabilize in 12 years old girls, while in the boys the development can occuruntil 14 years old [3]. However, the results of the present study showed a stabilization on foot segment changes that may be associated with the maturity level reached by the adolescents.

Relevance: Therefore, adolescents aged over 13 years do not seem to have significant changes in AI, regardless of gender. These results seem to indicate that the adolescents evaluated would have already reached the arch development, not showing more changes.

Figure 1. Comparison of the Arch Index between groups for adolescents of both sexes. No significant differences were found (p≤0.05).



Trial registration

This project and the experimental procedure was approved by the Local Research Ethics Committee (n° 3.641.611).

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Anatomical structures at risk in proximal fifth metatarsal fracture fixation: a cadaver study

Background: Fractures of the proximal fifth metatarsal have an increased risk for refracture, delayed union and nonunion secondary to poor blood supply to this área. They are usually treated conservatively, but when chosen for surgical treatment percutaneous fixation with screws is the most used. Few studies have evaluated the complications of injury to nearby structures during the percutaneous fixation. It has been shown, however, that the peroneal brevis and longus, the cuboid, and the sural nerve lie in close proximity to this starting point and are, therefore, at theoretical risk of injury. The study aims to evaluate the presence of injury of the structures at risk and to measure the distance of these structures to the entry point.

Methods: Eleven fresh-frozen below-the-knee specimens underwent standard operative fixation for a proximal fifth metatarsal fracture via the "High and inside" percutaneous technique. A guide wire was placed through the medullary canal and confirmed on fluoroscopy. The guide wire was left and the skin and subcutaneous tissues were carefully removed from the lateral midfoot to fully expose the structures at risk. The guidewire was then removed, and then the solid screw was placed. The distance of the wire in the base of fifth metatarsal and these structures was measured and documented, including the branches of the sural nerve, cuboid, fourth metatarsal, peroneus longus, and peroneus brevis tendons.

Results: The pin had damaged the peroneus brevis in 5 of 11 cadavers. However, it did not damage at the tendon insertion point in any specimen. The screw head contacted the articular surface of the cuboid in 3 of 11 cadavers.

Conclusion. We conclude that percutaneous fixation of fractures of the base of the fifth metatarsus presents a risk of partial lesion of the peroneus brevis tendon and lateral aspect of the cuboid. Therefore, specific care with these structures can be taken during the procedure.

Level 5 - Case report, Expert opinion, Personal observation

Key-Words: cadaver study, proximal fifth metatarsal fracture, fixation, Anatomical structures

Ankle dorsiflexion range of motion is related to pelvis kinematics during gait

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Introduction

Ankle dorsiflexion range of motion (ADF-ROM) contributes to the body forward movement during gait. Considering that the foot complex movement is coupled with the pelvis movement [1], inappropriate ADF-ROM may lead to altered kinematics in these segments to allow forward body motion during gait. In addition, studies have demonstrated that reduced ADF-ROM could affect temporal parameters in gait [2]. Therefore, this study investigated if ADF-ROM is associated with pelvis movements and temporal parameters during walking at a self-selected speed.

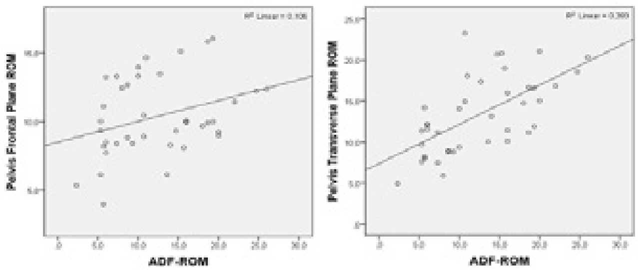
Methods

Sample: A convenience sample of 39 healthy individuals (16 men and 23 women) participated in this cross-sectional observational study (CAAE 84029718.6.0000.5149).
Inclusion criteria: (1) age between 19 and 44 years old; (2) no injury or surgery in the lower limbs or pelvis in the last six months; (3) shank-forefoot alignment angle smaller than 14°; (4) hip internal and external rotation ROM between 34 and 71°, and 25 and 56°, respectively, for women, and between 23 and 53°, and 29 and 56°, respectively, for men.
Exclusion criteria: Complaints of pain or discomfort during data collection.
Procedures: Clinical ADF-ROM was assessed using a goniometer, with the participant in prone with the knee extended. Kinematic data during self-selected walking speed were collected with a tridimensional motion analysis system.
Data reduction: Kinematic data of the dominant lower limb were analyzed. The amplitudes, in three planes, of pelvis movements relative to the lab, step length, and speed (normalized by limb length), and the time to the heel off (normalized by cycle time) were analyzed.
Data analysis: Pearson correlation coefficients were used to test associations between ADF-ROM and kinematic variables, considering $\alpha = 0.05$.

Table 1: Significant Pearson correlation coefficient between ankle dorsiflexion range of motion and kinematic variables during gait.

VariableS	r	p-value
Gait speed	.21	0.203
Time to heel off	.20	0.230
Step length	.37	0.022
Pelvis frontal plane ROM	.34	0.034
Pelvis transverse plane ROM	.63	< 0.001

Figure 1: Scatter Plots of pelvis kinematics amplitudes angles (°) (y-axis) versus the Ankle Dorsiflexion Range of Motion (ADF-ROM) angle (°) (x-axis) of correlations during gait. ROM – range of motion.



Results

Participants presented clinical ADF-ROM between 2.3° to 26°. Reduced ADF-ROM were associated with a shorter step length and reduced pelvis ROM in the frontal and transverse planes during the stance phase of gait (Table 1 and Figure 1).

Conclusions

Reduced ADF-ROM may limit tibia's anterior roll during the midstance phase and consequently reduce step length, compromising the movement of the body forward. This conjecture is supported by the strong association observed between ADF-ROM and pelvis ROM. Reduced pelvic ROM in the transverse plane during gait can increase the torsional stress on the lower extremity [3]the friction between the foot and the ground surface causes a free moment (FM, which is related to lower limb injuries, and reinforces the existence of biomechanical interactions between the foot and the pelvis [1].

Acknowledgments: CAPES, FAPEMIG, and CNPq.

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Ankle joint weightbearing CT three-dimensional distance maps of adult-acquired flatfoot deformity: a retrospective case-control study

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Introduction

Adult-Acquired Flatfoot Deformity (AAFD) can follow deltoid ligament failure and may lead to arthritis. Traditional two-dimensional (2D) radiographic assessment of AAFD can be inaccurate due to the complex three-dimensional (3D) configuration of the deformity. Instead, the structural alterations of the ankle joint alignment may be optimally characterized through weightbearing computed tomography (WBCT). This study aimed to use 3D distance maps (3DDMs) to objectively characterize the effects of AAFD on the tibiotalar joint under normal weightbearing conditions.

Methods

With IRB-approval, 20 stage II flexible AAFD and 10 control patients who underwent weightbearing CT (WBCT) were evaluated retrospectively. 3DDMs were generated from WBCT data across the entire tibiotalar interface. Each DM consisted of thousands of individual measurements across the talar dome, which was divided into a 3-by-3 grid to evaluate each region's coverage and distances.

Results

In AAFD feet, talar dome coverage was lower in the anteromedial (52.9%, $p<0.003$), anterior middle (32.0%, $p<0.02$), and anterolateral (29.4%, $p<0.02$) regions and higher in the posteromedial (42.5%, $p<0.009$), posterior middle (56.3%, $p<0.00002$), and posterolateral (84.0%, $p<0.0003$) regions. Similarly, the anteromedial (40.3%, $p<0.0006$) and anterolateral (42.6%, $p<0.002$) gutter coverage was significantly decreased, while the posteromedial (3.1%, $p=0.34$) and posterolateral (5.5%, $p=0.41$) gutter regions had non-significant decreases (Figure 1). The mean distances in the anteromedial (1.70mm), anterior middle (1.52mm), anterolateral (1.30mm), posteromedial (2.04mm), posterior middle (2.02mm), and posterolateral (2.35mm) talar regions in control patients were not significantly lower than in AAFD patients.

Conclusion

Our 3D distance map (3DDM) findings revealed significant differences in the position of the talus in patients with stage-II flexible AAFD when compared to the controls. There were decreases in the anteromedial, anterior middle, and anterolateral talar dome coverage along with increases in the posteromedial, posterior middle, and posterolateral talar dome coverage. These findings are consistent with increased plantar flexion and anterior translation of the talus relative to the tibia in patients with AAFD. However, none of the patients studied had indications of severe tibiotalar arthritis, found in the later stages of AAFD progression, as shown by the mean talar distances. This indicates that the 3DDMs from WBCT may provide early indication of previously underappreciated tibiotalar joint changes. Therefore, this novel 3DDM method can be utilized to quantify impact of the hindfoot valgus on the ankle joint in AAFD patients and may help identify or predict late complications like deltoid ligament rupture and ankle arthritis.

Figure 1. Average percentage change in each coverage region from the control AAFD patients. Bolded and starred regions denote significant changes.

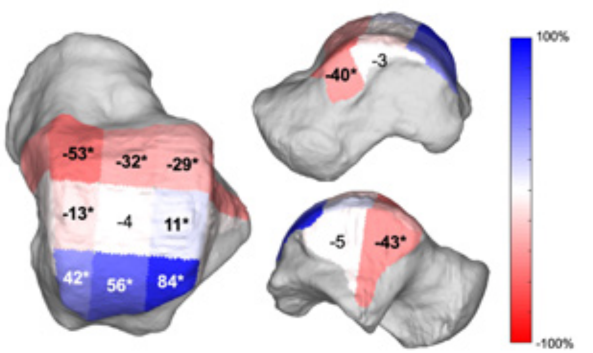
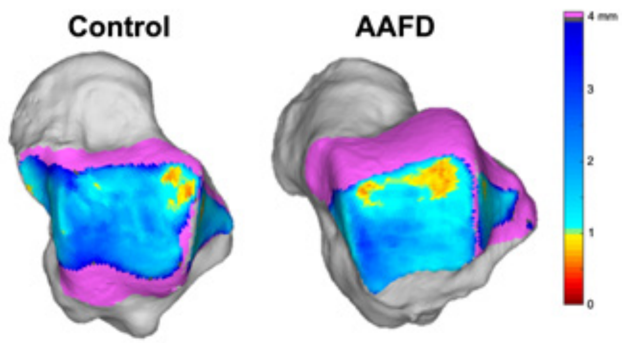


Figure 2. A comparison of 3DDMs between a control and an AAFD patient. Pink regions identify areas that were >4mm away from the opposing bone or were not covered.



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Ankle position does not affect electromyographic activity and muscle hypertrophy of knee flexor muscles during strength training protocol in trained individuals

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Introduction: Modify muscle length can influence its ability to generate tension and develop strength [1]. It was demonstrated that the peak of knee flexion torque was greater with the ankle in dorsiflexion [2]. However, the influence of different ankle positions on electromyographic activity (EMG) is still controversial. Also, no study has evaluated the effect of ankle position on muscle hypertrophy.

Objective: Analyze the effect of the ankle position in the hypertrophy and EMG of the biceps femoris long head (BFLH) muscle during prone hamstring curl exercise.

Methods: Nine adults (26±2 years) experienced with strength training (59±31 months) participated in the study. The muscle thickness of BFLH was measured with ultrasound in a B-mode (Saevo, Ribeirão Preto, São Paulo). Then, to analyze the EMG, wireless EMG sensors with 4 channels of 16-bit resolution (Trigno Lab Wireless, Delsys Inc., Boston, Massachusetts, USA) were positioned over the BFLH, medial (MG), and lateral gastrocnemius (LG) muscles. The data were acquired at a sampling frequency of 2000Hz. The magnitude of muscle recruitment was analyzed during the first training session. The BFLH muscle thickness was evaluated before and after 10-week training. The participants performed prone hamstring curl exercise unilaterally in two ankle conditions: plantar flexion (PF) and dorsiflexion (DF). The collection was performed intra subjects (each leg performed a condition). The training protocol (twice a week) consisted of four sets of maximum repetitions at 70%RM that were performed until the concentric failure for each leg in a 2:2 second cadence. The rest between sets was 90-seconds. After the last training session (minimum of 72 hours), the ultrasound measures were repeated. For statistical analysis, a paired t-test for EMG and a two-way ANOVA with repeated measures for muscle thickness were performed. The significance level was set at $p<.05$. for all these analyses.

Results: There was no significant difference in EMG for any analyzed muscle between dorsiflexion and plantar flexion conditions (Figure A). There was a significant difference in the biceps femoris's muscle thickness between pre and post moment in both conditions (Figure B). However, there was no significant difference in muscle thickness when compared to the conditions.

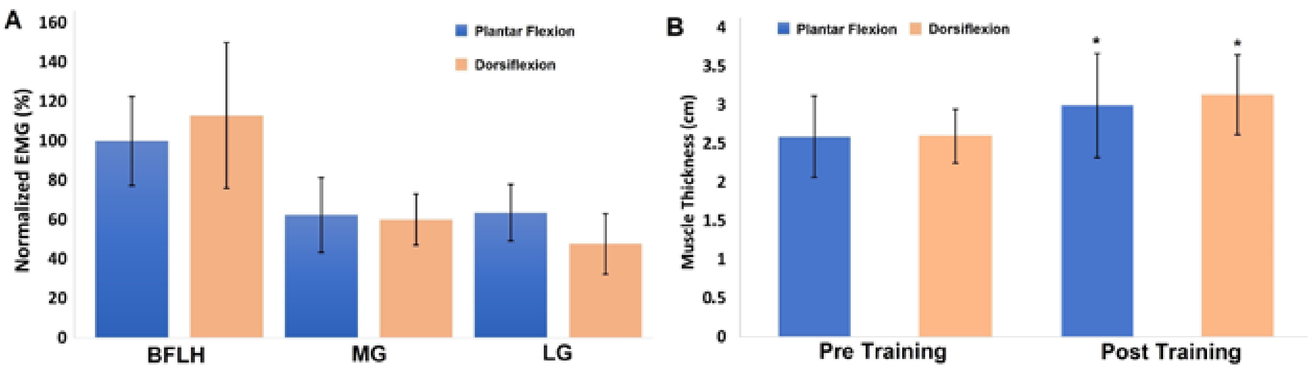

Figure 1. Normalized EMG data (%) of the analyzed muscle under different conditions (A). Muscle thickness pre and post-training (B). *Significantly different compared to pre training ($p<.05$).

Conclusion: The ankle position did not change the knee flexor muscles' EMG. Also, the training caused similar hypertrophy, regardless of the ankle position.

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AO type 43C tibial pilon fractures: what factors influence functional outcomes?

Objective: The objective of this study was to prospectively evaluate operated cases of AO type 43C tibial pilon fracture and assess which factors might influence functional outcomes during the late postoperative period.

Methods: Patients were classified according to the OTA/AO Classification using X-ray and computed tomography (CT) scans. Patients with type 43C fractures were included in this study. A total of 98 tibial pilon osteosynthesis surgeries were performed, and 35 cases were selected for this study based on the inclusion criteria. The treatment protocol established was based on the Tscherne Classification.

Results: We observed that immediate skin complications might be a prognostic factor for the late removal of osteosynthesis material (mean = 2 years postoperation) because an association was found between skin complications and the removal of osteosynthesis material. We observed a high incidence of late arthritis complications in both groups, which indicates that the post-traumatic arthritis associated with 43C pilon fractures is practically certain.

Conclusions: No differences were found between the groups when correlating the American Foot and Ankle Score (AOFAS), the degree of arthritis, and skin complications; therefore, complications did not determine the outcomes of tibial pilon fracture. Although the cartilage damage that occurs at the time of injury is a significant mediator of the clinical outcome, more important factors affect the final treatment outcome. In our study, these factors were the treatment protocol based on soft tissue involvement, the anatomical reconstruction of the joint, and rigid internal fixation with early range of motion.

Level of Evidence II; Therapeutic Studies; Comparative Prospective

Keywords: Tibial fractures; Intra-articular fractures; Fibula; Open fracture reduction; Surveys and questionnaires.

Artificial intelligence software to analyse custom insoles for feet deformity

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Background
Foot biomechanics is complex and abnormalities in the feet can lead to pain and disability. Custom-made insoles can correct foot biomechanics. Most systems to make custom insoles either use a foam box or some sort of pressure plate to analyse the shape and pressure of the contact surface of the feet. However, there are no studies looking at the correlation of custom insoles and the anatomical bone positions of the feet and what would be the optimum position. This study looks at the relationships between custom insoles and foot biomechanics by using new Artificial Intelligence (AI) software to analyse weight-bearing CT scans of the feet.

Methods
10 patients who had a variety of foot pathology and required custom insoles were selected for the study. The custom insoles were made using a pressure plate system (Orthema, Switzerland). The CT scans were done on a cone beam machine (Planmed, Finland) with the patients fully weight bearing. The AI software used is made by Disior (Finland).

Results
The results show that there was a change in the foot biomechanics. Specific measurements that were made were Meary's angle, Talocalconeal angle, and Medial distal tibial angle. These angles were measured using the AI software with the patient weight-bearing on their feet with and without insoles. All patients had improvement in the symptoms of their feet following use of the custom insoles. The foot biomechanics and changes in angles were not consistent in the group. There were a variety of changes in the angles with no clear correlation in the small number of the study of what the ideal angle should be for symptomatic improvement. However, this small study did prove the validity of using this software to analyse foot biomechanics for custom insoles.

Conclusion
This study shows that AI software can be used to analyse foot biomechanics for patients who need custom insoles for feet abnormality. Further work and study needs to be done to correlate with changes in foot biomechanics and the fitting of custom insoles to accurately determine what would be the optimum correction when making custom insoles or feet deformity.

Assignment of local coordinate systems during in-vivo kinematic analysis of the foot: a systematic review of the literature

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INTRODUCTION: The introduction of biplane fluoroscopy created the ability to measure and evaluate *in vivo* motion, enabling six degree-of-freedom examination of the tibiotalar and subtalar joints [1]. Although the International Society of Biomechanics defines a standard method of assigning local coordinate systems for the ankle [2], standards for the tibiotalar and subtalar joints are lacking due to variable methods for defining coordinate systems among investigators. The objective of this systematic review was to summarize and appraise existing literature that defines coordinate systems for the tibia, talus, and/or calcaneus.

METHODS: A systematic literature search was developed with the assistance of a health sciences librarian. Search results were limited to English Language from 2006 through 2020. Articles were screened by two independent reviewers based on title and abstract. Disagreements between the two raters were resolved through discussion with other co-authors. The methods used to define coordinate systems were extracted from included studies. The methodological quality of included studies was evaluated using a modified assessment tool based on the QUACS (Quality Appraisal for Cadaveric Studies) scale and metric introduced by Trinler et al [3,4].

RESULTS: The initial search resulted in 957 articles. Following screening, 52 articles met the inclusion criteria. Among the included articles, primary methods authors adopted for defining coordinate systems included: anatomical coordinate system (ACS) based on individual bone landmarks and/or geometric shapes, orthogonal principal axis, or interactive closest point (ICP) registration. The methodology scores and frequency of use for the most common coordinate systems are shown in Table 1. Figure 1 shows the most common landmarks and geometric shapes used on each bone. Methodological assessment of articles by two reviewers yielded 88% agreement. The overall quality of studies ranged from 61% to 97%.

DISCUSSION: Methods used to define coordinate systems in this review have positives and negatives. ACS is more prone to inter-user variability and principal axes may not accurately represent the joint articulation [5]. Principal axes have high reliability and consistency compared to ACS. ACS often aligns well with the functional axis of rotation whereas automated methods do not due to the high subject variability. Aligning coordinate systems with functional axes of rotation could help to reduce confusion when interpreting kinematic calculations across studies.

SIGNIFICANCE/CLINICAL RELEVANCE: A lack of consistency in methods used to establish coordinate systems in the ankle joint complex can have detrimental clinical effects if used for pre-surgical evaluation or post-operative assessment.

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Table 1. Coordinate systems used to describe ankle joint complex and corresponding average methodology scores.

Coordinate System	#of Times Used	Average Methodology Score
Landmark Anatomical	13	85.5%
Geometric Anatomical	11	87.5%
Landmark and Geometric Anatomical	16	90.3%
Principal Axes	7	84.3%
Iterative Closest Point	11	84.5%

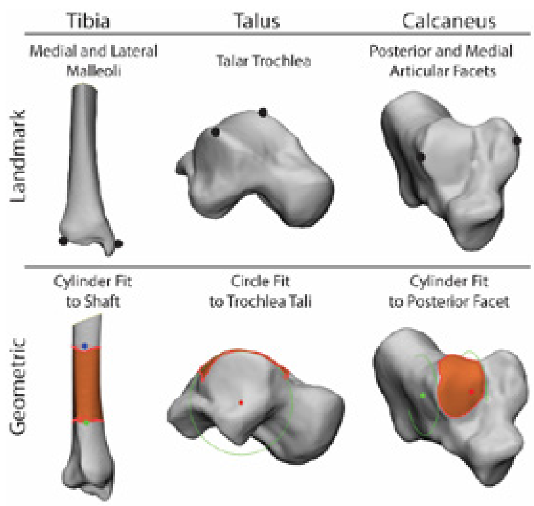

Figure 1. Common landmarks used in creating coordinate system identified

Association between foot mobility and strength of the foot's intrinsic muscles in recreational runners: a cross-sectional study

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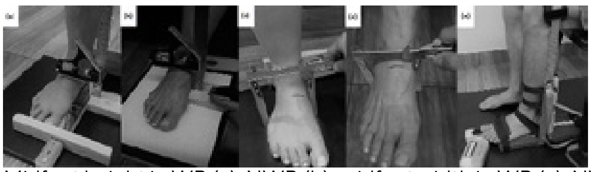
Background: The human foot is a structure having to be stable enough during foot-strike and push-off and mobile-compliant during stance phase of running [1]. However, the understanding of this dichotomous relationship in recreational runners is limited. The aim of this study was to evaluate if there is correlation between foot mobility and strength of the foot´s intrinsic muscles in recreational runners without musculoskeletal disorders.

Methods: 21 recreational runners without musculoskeletal disorders in lower limbs (6 women; 42 foots; age 33.90 ± 7 years; height 1.71 ± 0.07 m; weight 68.8 ± 9.47kg; 71.48 ± 56.96 months of running training) were evaluated. The difference in midfoot height (DIFFMFH) and difference in midfoot width at 50% of total foot length in non-weight bearing (NWB) and weight bearing (WB) was used to compose the general foot mobility (GFM) [2] (Figure 1, a-d). The force of the muscles that control the longitudinal arch of the foot (abductor hallucis, flexor digitorum brevis and quadratus plantae) [3] was measured with a load cell in a platform with a setup to stabilize the ankle-foot complex (Figure 1, e). The maximum isometric normalized force (NF) was obtained by the quotient of the subject´s intrinsic foot muscles isometric force capacity/(subject´s body mass*subject´s height). Pearson´s correlation coefficients (*r*) were calculated between DIFFMFH and NF, GFM and NF.

Results: There were no significant correlation between: DIFFMFH x NF (*r = 0.190, p = 0.228, 95% CI: -0.121 to 0.467*); GFM x NF (*r = 0.198, p = 0.208, 95% CI: -0.112 to 0.474*) (Figure 2).

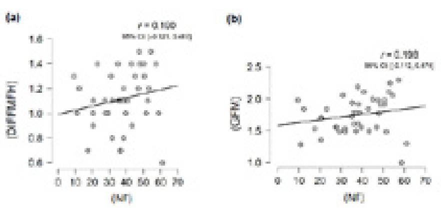
Conclusions: This preliminary study demonstrated no correlation between foot mobility and strength of the foot´s intrinsic muscles in recreational runners without musculoskeletal disorders in lower limbs. These results suggest some insights about running shoes choices, programs of prevention and rehabilitation in sports. Further studies are doing in runners with patellofemoral pain syndrome to understand this correlation in this population.

Figure 1



Midfoot height in WB (a), NWB (b), midfoot width in WB (c), NWB (d) and force measure of foot´s intrinsic muscles (e).

Figure 2



Scatter plots of the correlation between normalized force (NF) x difference in midfoot height (DIFFMFH) (a); NF x GFM (b). The linear regression line is superimposed to the data points.

Trial registration

Human Research Ethics Committee (University of São Paulo) (CAAE: 04404918.7.0000.5659)

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Automatic volumetric analysis of the distal tibiofibular syndesmotic incisura. A case-control study of subtle chronic syndesmotic instability.

Authors

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Introduction

Diagnosing injuries caused by chronic subtle distal tibiofibular syndesmotic instability (DTFSI) is challenging. Arthroscopic assessment is considered the gold standard. Weightbearing computed tomography (WBCT) recently emerged as a dynamic non-invasive diagnostic test. Our study aimed to develop and validate the use of this novel automatic 3D volumetric assessment of the incisura.

Methods

Patients with suspected DTFSI underwent WBCT examination before surgical treatment. DTFSI was confirmed by arthroscopic assessment. Control patients without history of syndesmotic injuries were included. The syndesmotic incisura volume (mm^3) was measured, and a 3D automatic measurement algorithm was performed. Measurements were compared between DTFSI patients and controls. A partition prediction model, ROC curves and area under the curve (AUC) were performed to assess the diagnostic accuracy of the automatic volumetric analysis to detect DTFSI. P-values of less than 0.05 were considered significant.

Results

In this preliminary report, four patients with DTFSI and seven controls were included. Mean value and 95% CI for 3D Syndesmotic Incisura volumetric measurements at 10 and 15mm points were: 1457 mm^3 (1233 to 1680)/2241 mm^3 (1951 to 2531) for controls, and 1679 mm^3 (910 to 2447)/2425 mm^3 (1408 to 3443) for patients with DTFSI (p-values of respectively 0.35 and 0.55). When comparing injured and uninjured DTFSI ankles, volume measurements at 10 and 15mm points were increased on injured ankles, with a Hodges-Lehmann difference of respectively 287 mm^3 (p=0.19), and 186 mm^3 (p=0.31).

The partition model demonstrated that the volume of the first 10mm was the best predictor of DTFSI, with only a 3% chance of DTFSI when the incisura volume was below 1291 mm^3 (AUC=0.71) (Figure 1).

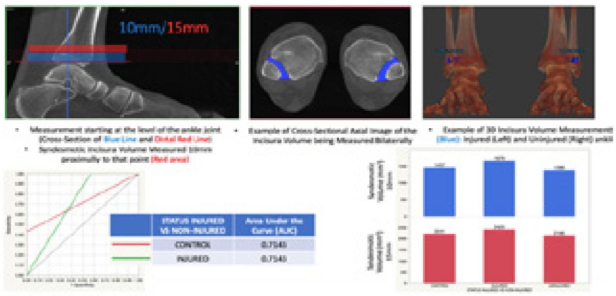

Figure 1. Example of measure methods and graphical plot representation of the results

Conclusion

Our results demonstrated increased volumes on injured ankles when compared to contralateral uninjured ankles and controls. Measurements performed within the first 10mm length of the syndesmosis were found to better predict the presence of syndesmotic instability, with a volume of 1291 mm^3 representing an important diagnostic threshold. Automatic 3D WBCT volumetric measurements may represent a useful non-invasive diagnostic tool for subtle and chronic syndesmotic instability.

Relevance

Automatic 3D volumetric assessment of the syndesmosis could provide a highly accurate, non-invasive method for diagnosing syndesmotic instability.

References

No references.

Balance and toe flexor strength correlate with intensity level of symptoms in menopausal women

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Introduction: Menopause symptoms and their severity vary from person to person due to several factors. Strength reduction of the muscles of the foot leads to an increased risk of falling and limitation of functional capabilities. Thus, the objective of this study was to verify the association of menopausal symptoms with the muscular strength of the toe flexors and the balance of menopausal women. Methods: After screening 48 women volunteered to participate in this study. They were divided into two groups namely a Menopausal Group with age of 55,08 ± 3,46 years old, body mass of 68,27 ± 9,00 kg, body height of 1,61± 0,07 m, body mass index of 26,24 ±3,17 kg/m^2, menopause duration of 4,29 ± 2,72 years, start of symptoms at 50 ± 3,52 years old and a Young Adult Women Group with age of 23,67 ± 3,06 years old, body mass of 57,94 ± 9,71 kg, body height of 1,62 ± 0,05 m, body mass index of 21,87 ± 2,82 kg/m^2. Symptoms were evaluated using the Menopause Rating Scale [1]. Baropodometry (Emed SF-2) was undertaken to evaluate plantar flexors strength of toes and hallux as well as bipodal quasi-static balance. Results: Menopausal women have different toe flexor strength and balance than those found in younger women (Table 1). Toe flexor strength measured by baropodometry correlates with the level of intensity of menopausal symptoms in the menopausal group. Discussion: In the present study there was a negative correlation between psychological and urogenital symptoms and one of the somatic symptoms with toe flexor strength. Relevance: Plantar pressure measurements already indicate a reduction of toe plantar flexor strength in midlife women. These findings contribute to the understanding of factors that may impair the physical health of menopausal women and that interventions may be performed earlier to promote better quality of life and preventing risk of fall.

Ethical Committee Approval Number: CAE2.950.687

Funding Acknowledgment: This research was supported by FAPESC

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Table 1: Plantar flexor strength in menopausal and young adult women

	Variiablel (unit)		Menopausal (n = 24)	Young Adults (n = 25)	
			x ±sd ou Md (interquartile range)		P
Plantar flexor strength – Right Limb	Toes	PF (N)	9,35 (9,71)	13,41 (13,18)	0,090[b]
		TPF (ms)	1580,00 ± 887,36	1465,12 ± 710,22	0,313[a]
	Hálux	PF (N)	11,13 (9,13)	13,02 (9,62)	0,222[b]
		TPF (ms)	1980,00 ± 671,98	1580,59 ± 455,03	**0,010[a]**

[a] probabilty of significance T test de comparison between independente groups; b probability significance U of Mann- Whitney Test (single-tailed, significant for $p<0,05$). PF, force peak ; TPF, time to force peak.

Biomechanical Evaluation of Arthroplasty in the First Ray of the Foot.

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Abstract. Hallux valgus and hallux rigidus are the most common pathologies in the first ray of the foot. Arthroplasty restores the function of the first ray but is a destructive surgical procedure. This abstract makes a comparation of two finite elements models, the first one is free of pathologies and the second one with an arthroplasty in the first ray using The Arthrosurface® ToeMotion® Modular Restoration System.

Introduction. Hallux valgus deviates in varus the first metatarsal while hallux is deviated in valgus. Hallux rigidus decreases the dorsiflexion of the first ray due to osteophytes and a retraction of the soft tissues of the plantar foot. Arthroplasty consists in replacing realigning or remodeling the skeletal muscle surface of an articular joint. To the date there is not a biomechanical evaluation of the implant researched in this paper.

Methods. For this project all elements (Figure 1) are considered like homogeneous, isotropic and linearly deformable bodies. The mechanical properties are defined in table 1. Border and load conditions are the same in the two models. In the distal phalanges of the lesser toes the rotation and translation in the vertical global axis of the model are restricted. Fixed supports are used in; the insertion surface of the Achilles heel, the second and first proximal phalanx. In the first step a pretension force of 2% is added to the muscles and in the second step the load corresponding to the person's own weight in the toe-off stage is added in the area where the fibula and tibial contact the talus. More details about the model can be seen in [1].

Results. In the arthroplasty model was observed that the first ray lost capacity to support charge and the second and third rays are overloaded.

Discussion. In the healthy model we can see the passive windlass mechanism while in the arthroplasty model this mechanism is lost (Figure 3).

Relevance. The process of arthroplasty in the model consists in disconnecting the muscles and tendons of; pedio, capsularis, flexor hallucis brevis, hallux abductor, hallux adductor and thin ligaments between the first metatarsal and the first proximal phalanx as well as to insert the implants (Figure 2). We encourage to physicians to evaluate the active windlass mechanism during follow up.

Materials	Elasticity modulus (MPa)	Poisson's ratio
Cortical bone	17000	0.3
Trabecular bone	700	0.3
Cartilage	10	0.4
Muscles	450	0.3
Thin ligaments	260	0.3
Plantar ligaments	350	0.3
Prosthesis (Co-Cr)	210000	0.29
Prosthesis (Ti-6Al-4V)	113800	0.29
Prosthesis (UHMW-PE)	650	0.3

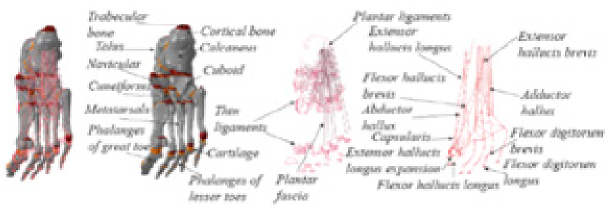

Figure 1

Figure 2

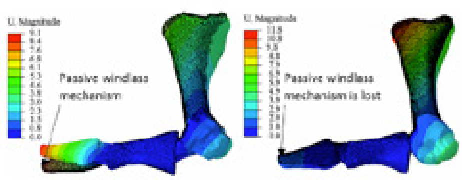

Figure 3

References.
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Biomechanics of midfoot Charcot neuroarthropathy in people with diabetes

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Introduction

Charcot neuroarthropathy (CN) is a rare and severe complication of diabetes characterised by fractures, dislocation and severe foot deformities. The aim of this study was to characterise joint kinematics and kinetics, lower leg muscle function and plantar pressure distribution using gait analysis.

Methods

Participants with diabetes and a diagnosis of midfoot CN confirmed by MRI were consecutively recruited across four clinics in NHS Lanarkshire, Scotland. Participants underwent 3D motion capture (Qualysis), EMG (Trigno™ Delsys) and plantar pressure analysis (Novel emed®). 3D kinematics and kinetics were derived from a five-segment musculoskeletal model in Visual 3D. EMG for tibialis anterior, lateral and medial gastrocnemius, soleus and the peroneals was recorded while plantar pressure was analysed for selected regions of interest. Results were compared to data collected previously from a healthy control group.

Results

Seven affected feet across different CN disease stages were studied. Key biomechanical differences were characterised by (1) Plantar pressure in the midfoot region was higher in the Charcot group than the healthy control group (662kPa vs 140kPa [mean difference -521.9, 95% CI -903, -141]): (2) Contact area for the midfoot contributed 29% of the total area of the foot for the Charcot group compared to 17% in the control group; (3) Intersegment kinematic patterns were highly variable between participants. There was reduced plantarflexion in the Charcot group between forefoot and rearfoot segments (0.7° vs 10.1°, [mean difference -9.4, 95% CI 15.2, 3.7]). Midfoot-to-rearfoot kinematics showed an increase in dorsiflexion in the Charcot group at 5.8° vs 3.2° (mean difference -2.6, CI -6.7,1.4); (4) The ankle plantarflexion moment was lower in the Charcot group (0.9Nm/kg vs 1.6Nm/kg [mean difference -0.7, 95% CI 0.9, 0.5]); (5) Ankle power was markedly reduced in the Charcot group (0.8W/kg vs 4.2W/kg [mean difference 3.5, 95% CI 2.9, 4.0]); and (6) EMG muscle activity was uniformly reduced on average at 0.1-0.2 normalised signal during weight-bearing with absent phasic patterns.

Discussion

Primary disease mechanisms associated with CN result in patient-specific alteration to foot structure and function. This was characterised by highly variable and patient-specific altered joint kinematics and kinetics, EMG-derived muscle function and plantar pressure distribution as well as global changes in gait pattern. Rocker-bottom deformity presented the most marked changes in intersegmental kinematics and disrupted plantar pressure distribution.

Clinical Relevance

Understanding patient-specific changes in foot structure and function in CN may help clinicians to evaluate, plan and treat the disease more effectively.

Biomechanics, physics, and evolution of foot arches

Madhusudhan Venkadesan

Yale University, Connecticut

The stiffness of the foot is important to support the forces of walking and running. In this talk, I show how the arches of the human foot enable such stiffness. In particular, the transverse arch of the tarsals in the midfoot is a crucial part of the foot's stiffness due to the principle of curvature-induced stiffness. Using mathematical models, physical mimics, and biological experiments we show how the transverse arch stiffens the foot. The principle is evident in a drooping currency note that significantly stiffens upon slightly curling it in the transverse direction.

Can current foot posture classification scores distinguish between pathological and non-pathological posture and has forefoot posture been included?

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BACKGROUND Foot posture has been shown to influence foot movements and pressure during gait [1,2], although it only has low statistical relationships with injury [1,3]. Multiple foot posture classification scores are available. However, the question remains, if they can be used to quantify pathologic foot posture [3,4]. Furthermore, studies with multi-segment kinematic foot models demonstrate the important role of the forefoot [5]. In addition, the distinct role of the human forefoot has been pointed out in evolutionary studies [6] and forefoot posture, in terms of transverse arch, has been related to gait kinematics and kinetics [7]. This study systematically reviewed foot posture classification scores, with the aim to analyze to what extent these scores are able to classify pathological posture and to what extent the forefoot posture is included.
METHODE A systematic review was performed with foot classification or posture related search terms (Table 1). The search terms resulted in a total of 978 records. The titles, abstracts and full texts of the found records were screened independently by two researchers. Finally, 15 articles were included in this study. An overview of the found foot classification scores was made and an analysis was performed on the inclusion of the forefoot posture. Furthermore, the ability of the classification scores to differentiate pathologic from non-pathologic posture was studied.
RESULTS Various simple and complex foot posture scores were found and mainly used to group foot postures into different types. Solely, the Foot Posture Index was used to differentiate the population into normal, abnormal and pathological groups [8]. Simple foot posture scores were almost exclusively related to the hind- and midfoot. Forefoot postures have been incorporated in several complex foot posture scores, but this sub-score is mostly limited to the forefoot posture in one plane: i.e., the transverse or frontal plane.
CONCLUSIONS Our findings suggest, that foot posture scores are not able to sufficiently quantify pathologies and the role of fore foot posture is underrepresented. Just as with other body parts, analyzing the posture of individual foot segments and their relation to possible structural and functional impairments, may be advantageous. However, more insight into individual functions of foot structures is then required.

Table 1. Systematic review search terms in Pubmed, Scopus, Web of Science including the filters 'Humans', 'English', 'German'.

Search terms	
((Classification foot posture) OR (screening protocol foot))	OR
((Screen foot structure) AND (Screen foot posture))	OR
((Classifying foot posture) AND (Foot pathology))	OR
(Classifying foot posture) OR (Screening foot posture)	OR
(Classify foot posture) OR (Classification foot posture)	

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Can foot and ankle movement patterns be used to distinguish running experience levels?

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Introduction: Running practice could generate musculoskeletal adaptations that modify the body mechanics and generate different biomechanical patterns for individuals with different levels of experience. The aim of this study is to compare the foot-ankle kinetic and kinematic patterns of recreational long-distance runners with different levels of experience in running practice using a machine learning approach.

Methods: Seventy-seven long-distance recreational runners (40.7±7.0yrs) were classified according to their running experience by a fuzzy classification system, which uses as input variables: (i) training frequency and (ii) volume, (iii) number of competitions and (iv) practice time [2]. The final experience score (0-10) was used to separate the subjects into: *less experienced* (x<5.0, n=25); *moderately experienced* (5<x<7, n=23); *experienced* (x≥7.0, n=29). They ran on an instrumented treadmill at a constant velocity (9.5-10.5km/h) for the biomechanical assessment. 3D-kinematics of the foot and ankle (IOR Foot Model) [1] and ground reaction forces (GRF) were acquired. The kinematic variables included: ankle (sagittal plane); rearfoot (frontal and horizontal planes); medial longitudinal arch; 1st metatarsal joint; angle between the calcaneus and metatarsal bones (all planes). Net ankle moments and powers, GRF vertical and anterior-posterior peaks and impulses, and vertical GRF loading rate were also calculated. The foot-ankle kinematic and kinetic time series underwent a principal component (PC) analysis for data reduction, and combined with the discrete GRF variables to serve as inputs in a support vector machine (SVM), in order to determine if the groups could be distinguished between them. In addition, 33 discrete biomechanical variables were extracted and compared between the experience groups using ANOVAs followed by Bonferroni post-hoc tests (P<0.05).

Results: Univariate analysis approach showed no between-group differences for the discrete variables. Three SVM models were built using a one-vs-all approach to discriminate one experience group at a time. All models successfully classified the groups (Table 1), with the sagittal ankle moments and power presenting a higher relative representation in the selected features more frequently.

Discussion: The classifier successfully separated runners of all experience levels based on the combination of foot-ankle biomechanical variables showing that foot mechanics are different according to running experience level.

Relevance: The fact that only the multivariate analysis approach identified differences in foot-ankle movement patterns between groups indicates that the combination of variables and the relationship between them can be more effective in identifying distinct running patterns.
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Table 1. Performance parameters of the studied models

	Accuracy criteria	Best model			Cross-validation model				
		Accuracy	MCC[a]	AUC[b]	Accuracy	Precision	Recall	F1-score	MCC
Less experienced x all	76.6%	83.1%	60.1%	80.7%	84.4%	64.0%	80.0%	71.1%	63.3%
Moderately experienced x all	77.9%	89.6%	75.4%	86.7%	88.3%	65.2%	100%	78.9%	72.3%
Experienced x all	71.4%	77.9%	51.7%	77.0%	80.5%	58.6%	77.3%	66.7%	57.9%

[a]Matthew correlation coefficient. [b]Area under the curve. [C]Cross-validation

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Can preoperative weightbearing CT alignment predict postoperative patient reported outcomes in adult acquired flatfoot deformity?

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Introduction: Adult acquired flatfoot deformity (AAFD) is a complex deformity that involves pathologic changes throughout the foot. Previous work has demonstrated the correlations between postoperative midfoot and hindfoot alignment and patient-reported outcomes. While this work has provided essential targets for surgeons performing flatfoot reconstruction, there is an absence of data that would enable surgeons to predict which patients are likely to have greater or less improvement after surgery based on their preoperative deformity. Furthermore, given the complex, multiplanar nature of the deformity seen in AAFD, plain radiographs alone may not provide enough detail to isolate individual elements of the deformity. Weightbearing CT (WBCT) allows for far more precise analysis in this regard. We hypothesized that there would be a set of parameters defining preoperative alignment on WBCT that would predict which patients are at risk for a lower magnitude of postoperative improvement in patient-reported outcomes (PROs).

Methods: In this retrospective IRB-approved study, patients that underwent surgical flatfoot reconstruction after having a preoperative standing WBCT were identified. Preoperative WBCT images were evaluated by two independent and blinded observers. Multiple parameters related to preoperative alignment and the severity of the AAFD were measured in the sagittal, coronal and transverse planes. Parameters measured included talus-first metatarsal angle; distances between the floor and the navicular, medial cuneiform and cuboid; subtalar joint horizontal angle; superior talar – inferior talar angle; subtalar joint subluxation; talonavicular uncoverage angle; hindfoot moment arm (HMA); and foot and ankle offset (FAO). Prospectively collected data regarding preoperative and postoperative PROs was evaluated. Six PROs components were assessed: physical function; pain interference, pain intensity, global mental health, global physical health and depression. Multivariate regression analysis and a partition prediction model were used to assess the correlation between preoperative alignment and improvement in PROs. P-values of less than 0.05 were considered significant.

Results: A total of 51 patients with a preoperative WBCT and postoperative PROs scores were identified and included. Multivariate regression analysis demonstrated that preoperative alignment significantly correlated with improvement in three out six components of PROs: pain interference, pain intensity and global mental health. The strongest predictor of improvement in PROMIS physical function t-score was medial cuneiform to floor distance, for pain interference t-score: cuboid to floor distance, for pain intensity: subtalar joint subluxation, for depression t-score: superior talar – inferior talar angle, and for global physical and mental health t-scores: sagittal talus-first metatarsal angle. Complete results are shown in Table 1 and Figures 1-6.

Discussion: Our analysis yielded readily identifiable cutoffs for WBCT measurements, where values above or below were correlated with significant differences in the magnitude of PRO score change. Interestingly, measures of sagittal plane collapse and hindfoot valgus were the most predictive of score changes.

Relevance: This data provides useful information for surgeons counseling patients prior to flatfoot reconstruction. Future work using this data to develop prediction models for postoperative outcomes would be valuable, as would studies using WBCT to evaluate the relationship between postoperative corrected alignment and PROs.

Table 1. Strongest predictive measures with cutoff values for each PROMIS subscore.

PROMIS Subscore	WBCT Parameter	Cutoff Value	Mean subscore improvement ≥ cutoff value (n, SD)	Mean subscore improvement < cutoff value (n, SD)
Physical Function	Medial Cuneiform – Floor Distance	10.1 mm	6.264 (45, 6.474)	15.533 (6, 14.617)
Pain Interference	Cuboid – Floor Distance	19.5 mm	-7.3 (5, 18.929)	9.004 (46, 7.851)
Pain Intensity	Subtalar Joint Subluxation	15%	13.37 (20, 28.379)	34.232 (31, 18.001)
Depression	Superior Talar – Inferior Talar Angle	35.3°	23.6 (5, 27.829)	3.483 (46, 16.265)
Global Physical Health	Sagittal Talus – First Metatarsal Angle	21.1°	24.646 (13, 23.908)	41.482 (38, 20.668)
Global Mental Health	Sagittal Talus – First Metatarsal Angle	25.1°	21.2125 (8, 23.211)	42.486 (43,21.360)

SD = Standard Deviation.

Figure 1. Physical Function Decision Tree

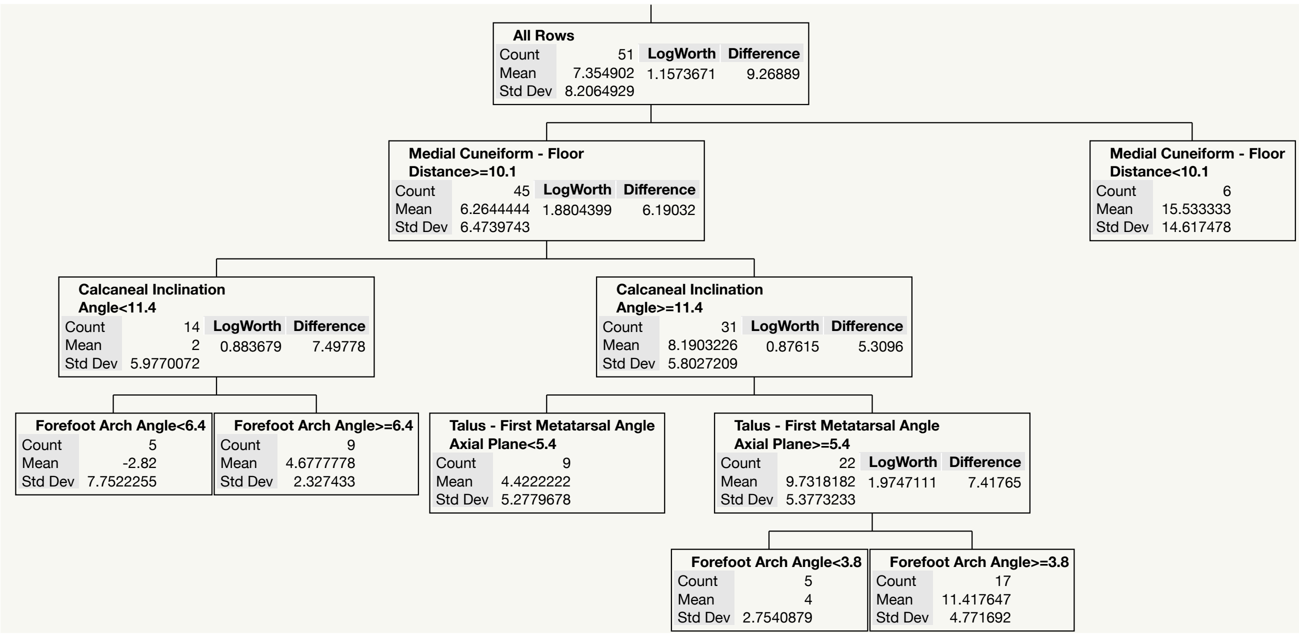


Figure 2. Pain Interference Decision Tree

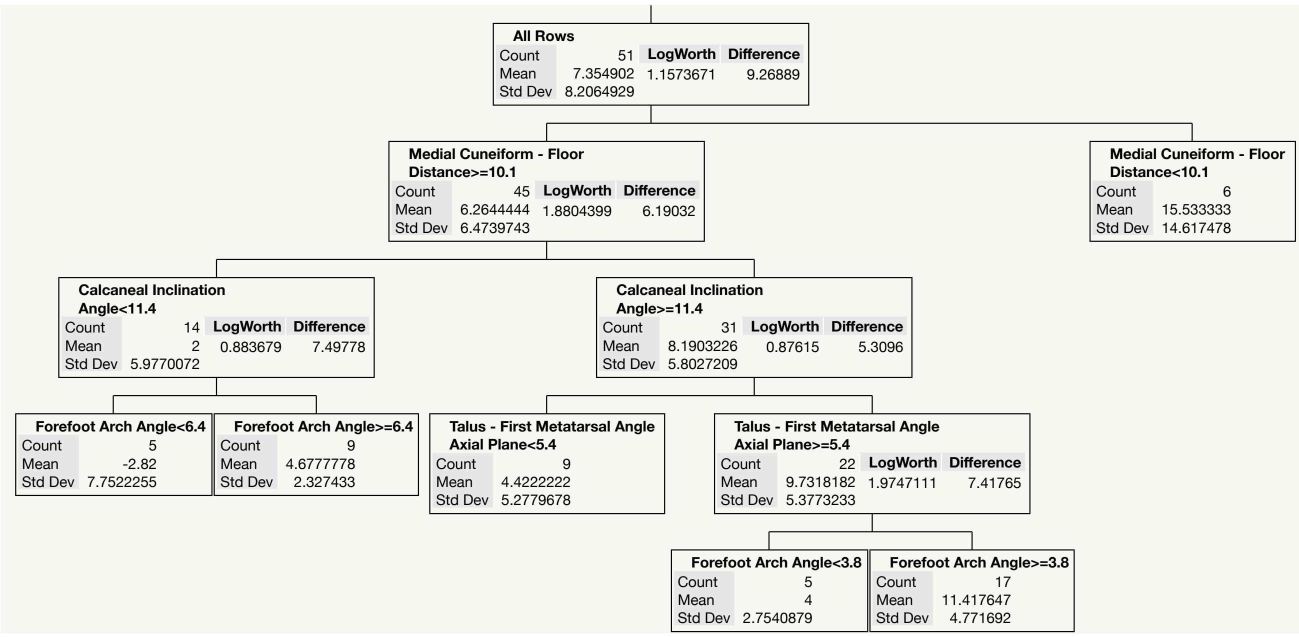


Figure 3. Pain Intensity Decision Tree

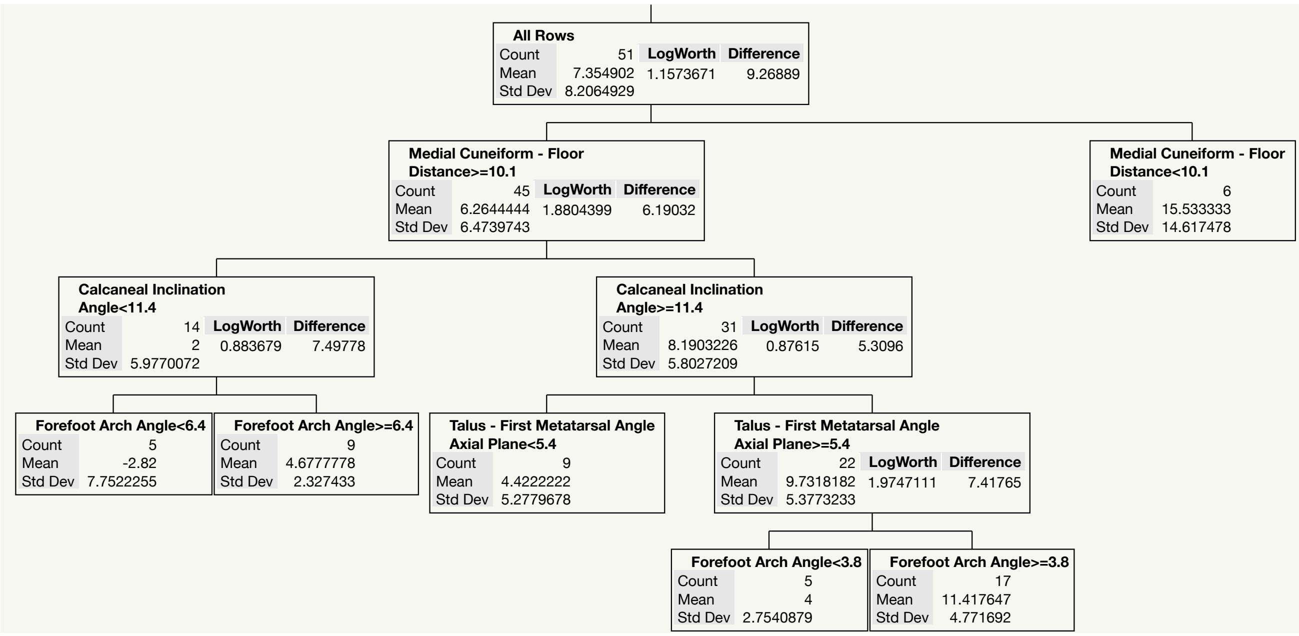


Figure 4. Depression Decision Tree

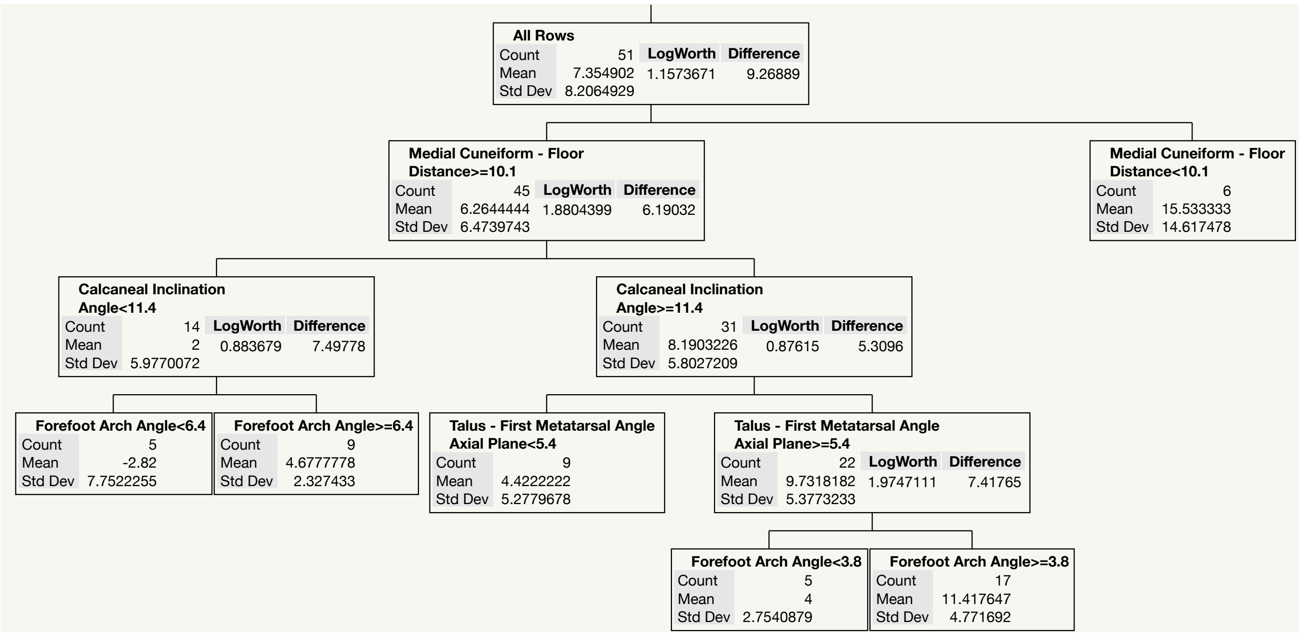


Figure 5. Global Physical Health Decision Tree

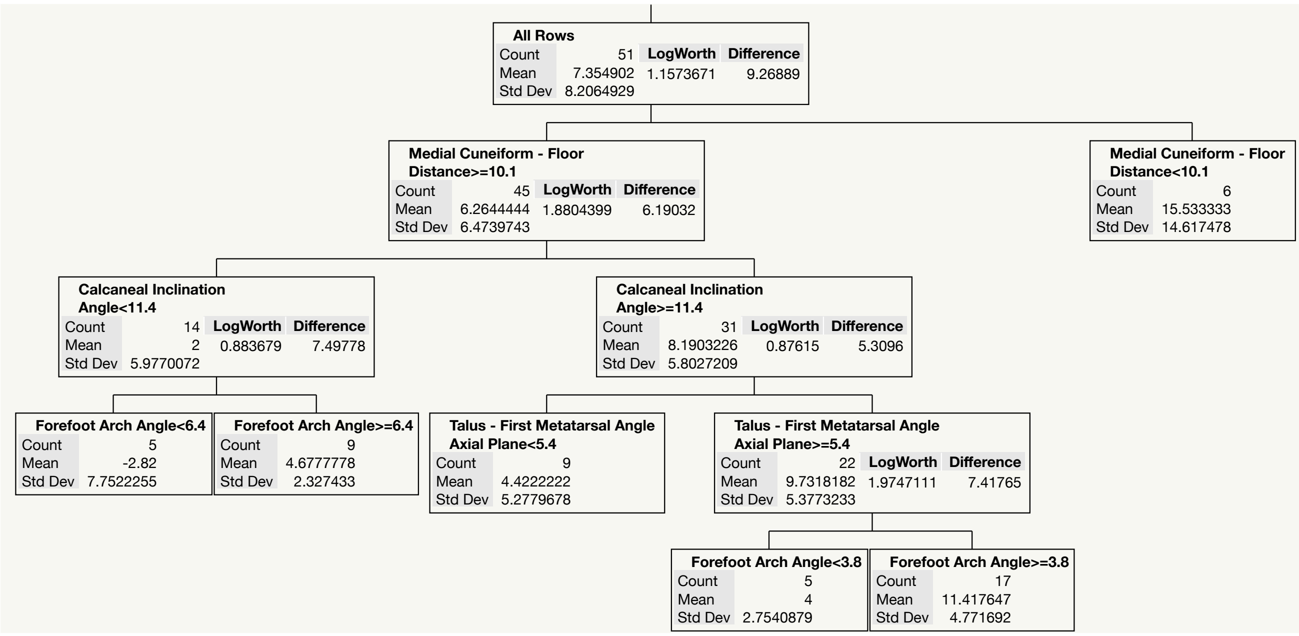
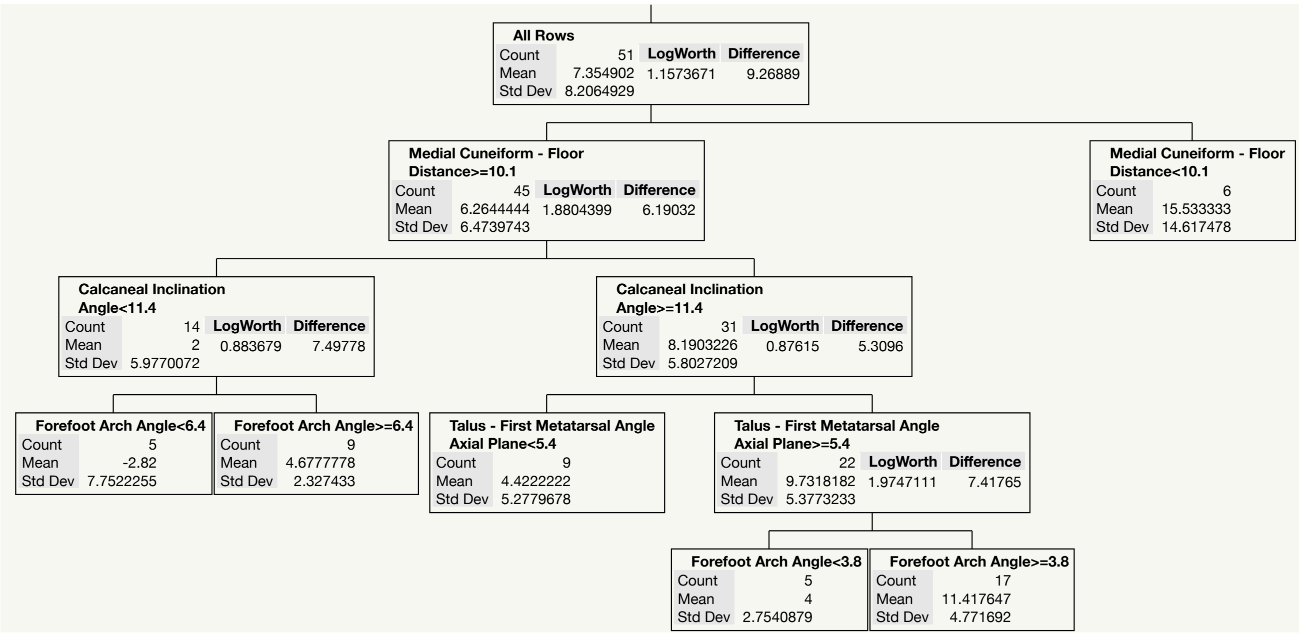


Figure 6. Global Mental Health Decision Tree



Can the ankle joint moment assessed using a pressure plate only?

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Background: The ankle moment is an important parameter in assessing gait. It is most commonly measured using a 3D-gait analysis system, which is, however, time consuming and expensive. A pressure plate could be an alternative because it measures the vertical ground reaction force and the center of pressure relative to the pressure pattern of the foot on which the ankle axis could be projected.

Objective: This study investigates the ability of the pressure plate to calculate the ankle joint moment and determines the best general ankle axis location and orientation.

Materials & Methods: Fifteen healthy subjects and nine patients with neurological disorders were recorded during barefoot walking with a 3D motion capture system (Vicon) and a pressure plate. Healthy subjects walked at preferred (PREF) and slow (SLOW) walking speed. The ankle joint axis on the pressure pattern was defined as the location which resulted in the smallest ankle joint moment error compared to the moment calculated by Vicon's Plug-in-Gait (PGM). The orientation of the axis was determined as the angle of the axis with the sagittal and frontal plane.

Results: The best axis for the flexion/extension moment was located at 25% of normalized foot length. Correlation coefficients between PGM and pressure plate flexion/extension moment were above 0.99 and root mean squared values were small. The inversion/eversion ankle joint axis orientation as defined by PGM showed large variations across subjects on the plantar pressure pattern. Correlation coefficients around 0.8 and relatively high RMS values between PGM and pressure plate inversion/eversion moment were found.

Discussion: This study showed that the flexion/extension moment can be accurately assessed by a pressure plate. Further research with biomechanical foot models should determine the best axis location and orientation to calculate the inversion/eversion moment.

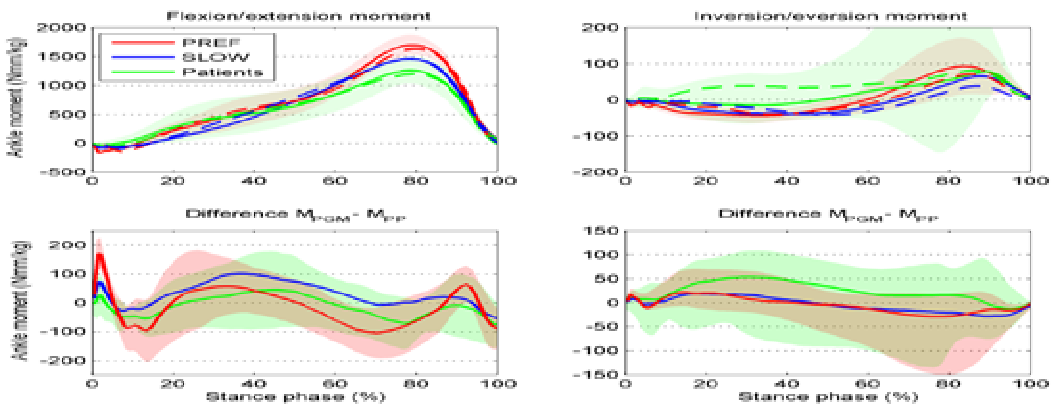

Figure 1. Average ankle joint moments for flexion/extension (left panel) and inversion/eversion (right panel).

Changes in Morphology of the Haemophilic Talus

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Morphological changes to the talocrural joint are observed clinically in haemarthropathy[1] as structural and functional changes advance, however they have not been quantified. In order to more robustly assess the nature and degree of morphological change, measurements were derived from MR images for a haemophilic group and a sex-matched non-diseased control group.

Four measurements were taken, using ImageJ (1.52v), from sagittal MRI projections at three locations – medial, lateral and central: Trochlear Tali Arc Length (TaAL), Talar Height (TaH), Trochlear Tali Length (TaL), and Trochlear Tali Radius (TaR). These measurements were used to generate three ratios of interest: TaR:TaAL, TaAL:TaL, and TaL:TaH. With the hypothesis of a flattening of the talar dome with haemarthropathy, it was expected that TaR:TaAL and TaL:TaH should be greater for haemophilic ankles, and TaAL:TaL should be smaller.

Non-diseased control measurements were validated against morphological studies carried out on radiographs and CT images, before assessing the difference between the ratios for non-diseased (33 images from 11 control ankles) and haemophilic ankles (93 images from 8 patients' ankles) (ethics: MEEC 18-022).

The haemophilic talus indicated collapse in the medial and lateral regions in all three ratios with the greatest degree of collapse in the medial talus (TaR:TaAL increased by 20.7%, TaAL:TaL decreased by 5.9% and TaL:TaH increased by 23.5% ; t-test at $p<0.05$), followed by the lateral talus (TaR:TaAL increased by 3.4%, TaAL:TaL decreased by 5.5% and TaL:TaH increased by 18.4% ; t-test at $p<0.05$). The changes in lateral TaR:TaAL were not found to be statistically significant; none of the three ratios showed statistical differences for the central talus.

The results demonstrate non-uniform influence of haemarthropathy across the talus, with increased influence at the medial and lateral talar extremes, and relatively healthy values seen in the centre. The morphological response was however unique to each haemophilic ankle, with respect to both degree of change, and progression with time. Disease progression was assessed for the eight haemophilic ankles over a range of time periods (6-112 months) – each indicated an individual response with time, not always tending towards collapse.

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Changes in plantar load distribution in visually-impaired subjects

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Background: The consequences of the visual deprivation to the balance control can be investigated in subjects with visual impairment, and controversial findings have been reported about the modifications of the visually impaired subjects [1,2,3]. We aimed to compare the center of pressure and pressure in the feet plantar surface measured by sighted and visually impaired subjects.

Methods: Our sample comprised 36 subjects (18 sighted participants, 18 visually impaired participants) that stood in normal quite stance in a baropodometric resistive plate for simultaneous data acquisition of the center of pressure (COP) displacement and barefoot plantar pressures in open and closed eye conditions.

Results: Both groups had no differences between the COP displacement and area in both eyes aperture conditions (Table 1). Visually impaired participants had increasing of the pressures in the metatarsal region compared to the sighted participants at both viewing conditions (Figure 1 and Figure 2). A linear discriminant analysis showed that pressures in the plantar surface of the feet were better than the stabilometric parameters (COP displacement and area) to separate both groups.

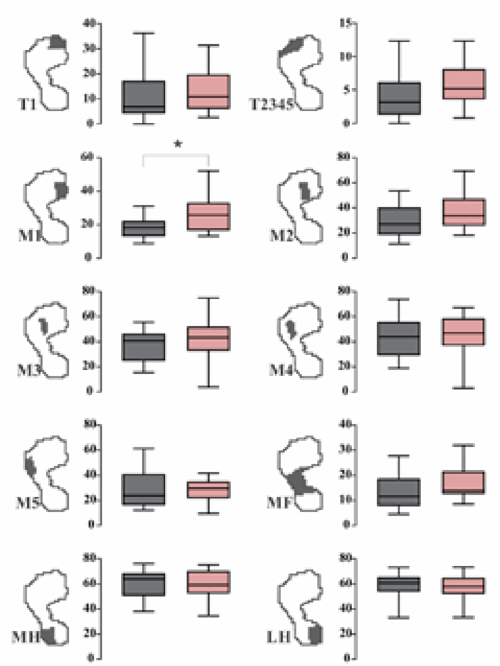
Conclusion: Our findings suggest that the mechanism of static balance disturbance in blind people is started by increasing of the plantar pressures in the forefoot with no or few balance deficits.

Table 1. Descriptive statistics of the stabilometric parameters of the sighted and visually impaired groups represented by median and interquartile range.

	Sighted group	Visually impaired group	p*
Open eyes condition COPdisp[a] (mm)	327.5 (93.1)	309.9 (73.2)	0.81
COParea[b] (mm2)	87.7 (72.6)	68.3 (72.6)	0.92
Closed eyes condition			
COPdisp[a] (mm)	351.3 (48.3)	318.3 (114.4)	0.24
COParea[b] (mm2)	110.6 (109.1)	73.7 (58.8)	0.49

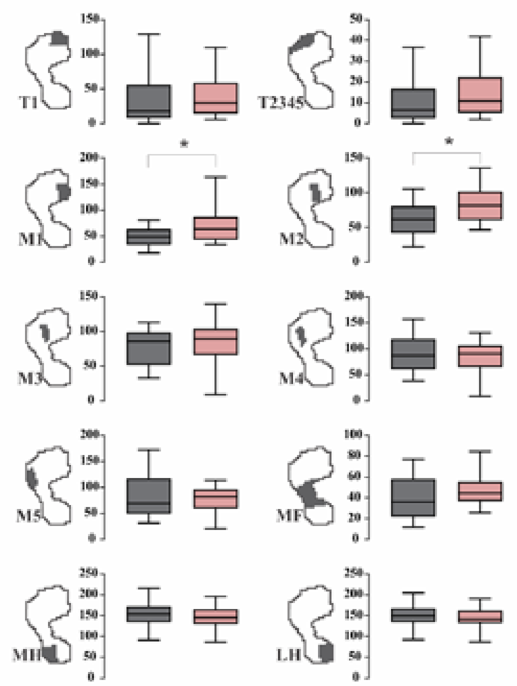
[a] center of pressure displacement. [b] total area of the center of pressure.

Figure 1. The mean plantar pressures in open eyes conditions



T1: Toe 1. T2345: Toe 2, 3, 4 and 5. M1: Metatarsus 1. M2: Metatarsus 2. M3: Metatarsus 3. M4: Metatarsus 4. M5: Metatarsus 5. MF: Medium Foot. MH: Medial Heel. LH: Lateral Heel.

Figure 2. The mean plantar pressures in closed eyes conditions.



T1: Toe 1. T2345: Toe 2, 3, 4 and 5. M1: Metatarsus 1. M2: Metatarsus 2. M3: Metatarsus 3. M4: Metatarsus 4. M5: Metatarsus 5. MF: Medium Foot. MH: Medial Heel. LH: Lateral Heel.

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Clinical relevance of the plantar anatomical masking for plantar loading analysis in diabetic foot

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Introduction Biomechanical assessment of foot function often relies on the analysis of pressure-related parameters under specific regions of the foot (ROIs) [1]. In patients with Diabetes, who often develop foot deformities especially at the forefoot and toes, the accurate identification of plantar regions with altered loading parameters is a crucial issue [2]. We developed a peculiar anatomical mask (DIAB) to effectively define 7 ROIs. Main aim of this study was to investigate reliability and clinical relevance of the mask in people with Diabetes, focusing on the forefoot loading.

Methods Three groups, 10 participants each, were assessed: Diabetics (DG: age 55.2±10.8, BMI 30.7±5.8, AI 0.25±0.03), Diabetics with neuropathy (DNG: age 59.9±14.8, BMI 25.1±3.4, AI 0.26±0.02), Controls (CG: age 46.5±6.8, BMI 27.4±6.0, AI 0.22±0.06). They were assessed through integrated plantar pressure (EMED q-100) and kinematics (VICON) measurements during three consistent gait trials. The Oxford Foot model marker configuration was used, with an additional marker between I and II MTH. DIAB defined 7 ROIs: hindfoot and midfoot [1], lateral, central and medial forefoot, hallux and 2-5 toes. The reference geometrical mask (REF) was obtained by collapsing metatarsals 2-4 ROIs of the Novel® 10-ROIs mask (Fig.1A). DIAB reliability was investigated by comparing the 2 masks (intra-subject coefficient of variation (CV); non-parametric coupled test, $p<0.05$), for all ROIs and 7 parameters namely contact area, maximum force (MF), peak pressure (PP), maximum mean pressure, contact time, pressure-time integral (PTI) and force-time integral (FTI). Clinical relevance was explored on loading of the 3 forefoot ROIs (ANOVA with Bon-Holm correction, adj $p<0.05$).

Results As for reliability, CV of DIAB was comparable ($p>0.05$) with CV of REF in 47% of the 49 comparisons, lower in 43%, higher only in 5 parameters of the midfoot (10%). As for clinical relevance, the 2 masks equally well discriminated forefoot PP and PTI between the groups, with DIAB additionally discriminating between CG and DG PP in the central forefoot ($p=0.0225$; PP(kPa): 579±213 in CG, 428±193 in DG). For normalized MF and FTI, DIAB better discriminated CG and DG in lateral forefoot (MF and FTI), and CG and DNG in central (MF) and medial (FTI) forefoot (Fig 1B).

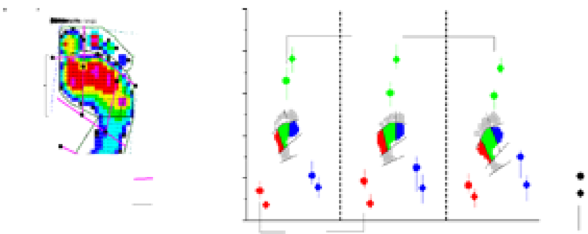

Figure 1. (A) Representative differences in ROI boundary definition in DIAB and REF. (B) Adaptation of box charts of MF in forefoot ROIs, for the three groups and the two masks.

Discussion & Relevance Investigation on intra-subject variability showed DIAB can be reliably used independently of the foot type. Despite the high intra-group variability, DIAB showed an encouraging increased clinical relevance with respect to REF in discriminating pathology-related forefoot ROIs so as to better and earlier addressing therapeutic strategies.

Trial registration NCT02790931 (http://clinicaltrials.gov/)

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Comparative Ankle Kinetics of Idiopathic Toe Walking

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Introduction

Toe walking is characterized by the inability or limitation to contact the heel during the initial contact phase of gait [1], [2]. This pattern is recognized to be normal within the maturation process of gait, however, persistent toe walking beyond the age of 3 years, could be an indicator of orthopedic or neurological impairment [3]. Nevertheless, the condition is described as idiopathic, as a diagnose of exclusion [4], [5]. Current research has been studying if actually there is not impairment, since there could exist some indicators of neurological damage of a minimal extension, expressed as altered sensory processing or motor skills disorder [6]–[9].

Methods

Gait pattern was evaluated in five children between 7 and 10 years old, diagnosed with idiopathic toe walking using VICON movement analysis system. First, subjects' usual toe pattern was captured, using the command "Just Walk"; then, they were asked to walk forcing heel strike. Ankle internal moment was calculated in three specific parts: maximum dorsiflexion moment (0 to 12% of gait cycle), maximum plantarflexion moment in mid-stance (12 to 30% of gait cycle) and maximum plantarflexion moment in terminal stance (40 to 60% of gait cycle). A Wilcoxon test was used to determine statistical differences between kinetic data of normal gait, forced heel strike gait, and toe walk pattern.

Results

Subjects showed in the musculoskeletal assessment diminished dorsiflexion ROM and positive Silfverskiold test, for both ankles. Table 1 summarizes the results of statistical analysis of the gait variables referred previously.

Table 1. Comparison between toe walking, forced heel strike and normal gait patterns.

	Z	p-Value
Maximum Dv[d] HSF[e] vs Maximum Dv ITW[f] (0 – 12% GC[g])	-2.549[a]	0.011
Maximum Pv[h] HSF vs Maximum Pv ITW MS[i] (12 – 30% GC)	-2.701[a]	0.007
Maximum Pv HSF vs Maximum Pv ITW TS[j] (40-60% GC)	-0.866[b]	0.386 (NS)[c]
Maximum Dv N[k] vs Dv ITW (0 – 12% GC)	-2.869[a]	0.004
Maximum Pv N vs Maximum Pv ITW MS (12 – 30% GC)	-2.701[a]	0.007
Maximum Pv N vs Maximum Pv ITW TS (40-60% GC)	-1.988[b]	0.047
Maximum Dv N vs Dv HSF (0 – 12% GC)	-2.194[a]	0.028
Maximum Pv N vs Maximum Pv HSF MS (12 – 30% GC)	-0.663[b]	0.508 (NS)
Maximum Pv N vs Maximum Pv HSF TS (40-60% GC)	-2.499[b]	0.012

[a] Negative Rank. [b] Positive Rank. [c] Not Significant ($p > 0.05$). [d] Dorsiflexion value. [e] Forced Heel Strike. [f] Toe Walking. [g] Gait Cycle. [h] Plantarflexion. [i] Midstance Phase. [j] Terminal Stance Phase. [k] Normal moment value

Discussion

Results between toe walking and forced heel strike, show the ankles have poor dorsiflexion moments during load response, and a rapid increase in plantarflexion moments describing a double-hump shape during stance, similar to Perry et al. [10]. This is associated with early energy absorption, which quickly transitions to abnormal energy generation during mid stance. However, an appropriate power generation was found during pre-swing, similar to other studies [11]. When comparing forced heel strike pattern to normal gait values, the dorsiflexion moments during the load response were not fully improved, but during mid-stance the second ankle rocker was present as described by Westberry et al. [12], although in our results, the plantarflexion peak in the terminal stance was still below the normal values.

Relevance

The inability to normalize on demand the kinetic variables of heel pattern during gait, for toe walkers, could be an indicator of the presence of mild neurological impairment.

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Comparison between cotton test and tap test for the assessment of coronal syndesmotic instability: a cadaveric study

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Introduction

Detection of subtle syndesmotic instability (SI) is challenging and the dynamic nature of the widely used Cotton test presents inconsistencies in the distraction force magnitude and direction when pulling the fibula away from the tibia while maintaining correct radiographic positioning. The novel Tap test advances a cortical tap through a drilled hole in the fibula with a stable, unidirectional distraction force applied to the tibia. We aimed to compare the diagnostic accuracy of the Tap and Cotton tests for coronal SI.

Methods

Tibiofibular Clear Space (TFCS) of 10 cadaveric specimens was measured for: intact, non-stressed; intact, stressed (Tap and Cotton tests); injured, non-stressed; and injured, stressed (Tap and Cotton tests). TFCS values were compared by paired Wilcoxon. Diagnostic performance was assessed using a relative increase of TFCS>2mm when comparing intact stressed and injured conditions. P-values <0.05 were considered significant.

Results

The intraclass correlation coefficient (ICC) for intraobserver and interobserver reliability was respectively, 0.96 and 0.78, both considering potential bias and interactions. TFCS measurements were similar in intact non-stressed, intact stressed (Cotton and Tap tests) and injured non-stressed conditions, with mean values and 95% Confidence Intervals of: intact non-stressed, 3.5mm (CI, 3.0 - 3.9mm); intact stressed, 3.6mm (3.1 - 4.1mm) (Cotton test) and 4.0mm (3.5 - 4.5mm) (Tap test); injured non-stressed, 3.8mm (3.3 - 4.3mm). TFCS was significantly increased (p<0.0001) in injured and stressed ankles for Cotton and Tap tests, with values of respectively, 6.2mm (.8 - 6.7mm) and 6.1mm (5.7 - 6.6mm). A graphical plot comparing all mean values is presented (Figure 1). Example fluoroscopic Mortise images are presented (Figure 2). The Cotton test had 73.3% sensitivity, 100% specificity, and 86.7% diagnostic accuracy. The Tap test had 70% sensitivity, 90% specificity, and 80% diagnostic accuracy.

Conclusion

Our cadaveric study compared the Cotton and Tap tests for detection of coronal plane syndesmotic instability. Both demonstrated similar increases in the tibiofibular clear space (TFCS) measurements in stressed injured conditions when compared to intact non-stressed and stressed conditions, as well as injured non-stressed conditions. Additionally, both tests demonstrated similar diagnostic accuracy for coronal plane syndesmotic instability, with slight favor for the Cotton test. In our experience of the Cotton test, it is difficult to apply a steady distraction force while maintaining a perfect Mortise view and the test is frequently not reproducible. We recommend the Tap test as a more stable, controlled, and reproducible intraoperative diagnostic test for coronal plane syndesmotic instability.

Figure 1. Tibiofibular Clear Space (TFCS) Measurements By Ankle Conditions (Intact Non-Stressed, Intact Stressed, Injured Non-Stressed, and Injured Stressed).

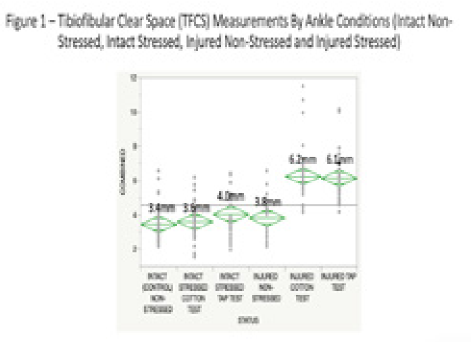
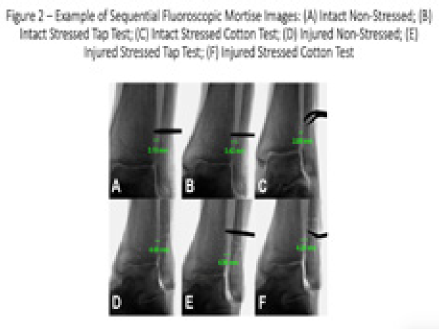


Figure 2. Example of Sequential Fluoroscopic Mortise Images: (A) Intact Non-Stressed; (B) Intact Stressed Tap Test; (C) Intact Stressed Cotton Test; (D) Injured Non-Stressed; (E) Injured Stressed Tap Test; (F) Injured Stressed Cotton Test



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Comparison of the rigidity and forefoot – rearfoot kinetics from three forefoot tracking marker clusters during the stance phase of walking

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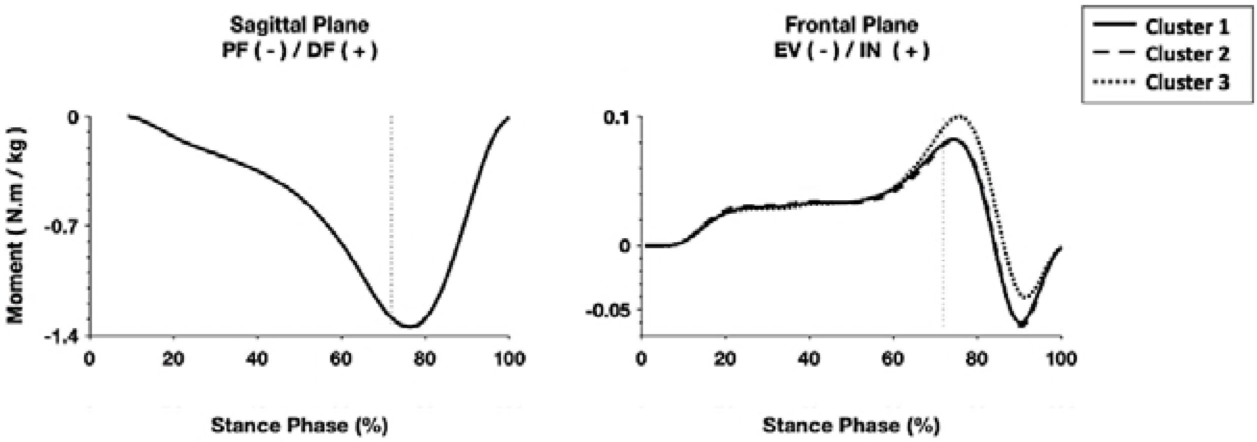
Body segments such as the forefoot clearly have non-rigid behavior due to the mobility of the metatarsal bones. Therefore, different parts of the forefoot chosen for tracking its motion may reveal different forefoot – rearfoot kinetics [1]. Hence, the present study aimed to compare the rigidity as well as the forefoot – rearfoot kinetics obtained from three forefoot tracking marker clusters during walking. Nineteen healthy adults performed six valid walking trials recorded by an optoelectronic system (eight cameras ProReflex, Qualisys, Sweden) synchronized with two in-line force plates (OR 6-7, AMTI, USA). Rearfoot's and forefoot's coordinate system were equal for all clusters [2, 3], only the forefoot's tracking markers locations varied among them. Cluster 1: a typical cluster, focusing on the proximal forefoot [2, 3]. Cluster 2: a second typical cluster, focusing on the distal forefoot and outer metatarsals [4]. Cluster 3: a new cluster proposition, focusing on the distal forefoot and central metatarsals [1]. Cluster rigidity was estimated by means of the segmental residual normalized by the average inter-markers distance using the goodness of fit (least squares fit method), which represents the relative motion among the markers due to equipment noise, soft tissue motion, and rigid body violations. Forefoot – rearfoot moments (Nm/kg) were calculated using inverse dynamics of the forefoot motion relative to the rearfoot. Plantarflexion, inversion and eversion moment peaks were chosen for the analysis. Repeated-measures ANOVA with pairwise comparisons revealed that the cluster 3 had the smallest residual in comparison with the other two clusters. The plantarflexion moment peaks from clusters 1 and 3 were not different, and both were higher than the cluster 2. Cluster 3 presented the highest inversion moment peak and the lowest eversion moment peak in relation to the clusters 1 and 2, with no difference between these last two clusters. These results are present in Table 1 and Figure 1. In conclusion, as these clusters capture the motion of different parts of the forefoot, they indeed revealed different forefoot – rearfoot kinetics. When the objective is to maximize the cluster rigidity, the new forefoot tracking marker cluster proposition (cluster 3) can be recommended.

Table 1. Comparative table among the three marker clusters for tracking the forefoot motion during walking.

Variable	Mean (SD)			ANOVA		Contrasts		
	Cluster 1	Cluster 2	Cluster 3	*P*	F	C1 x C2	C1 x C3	C2 x C3
Forefoot Residual	2.27E-2 (0.47E-2)	2.23E-2 (0.51E-2)	1.81E-2 (0.40E-2)	<0.001 *	16.544	0.732	<0.001 **	<0.001 **
PF Moment Peak (Nm/Kg)	-1.40 (1.62E-1)	-1.41 (1.62E-1)	-1.40 (1.62E-1)	<0.001 *	10.641	<0.001 **	0.280	0.004 **
IN Moment Peak (Nm/Kg)	0.14 (0.11)	0.14 (0.11)	0.15 (0.12)	0.020 *	5.849	0.730	0.034 **	0.003 **
EV Moment Peak (Nm/Kg)	-0.07 (0.04)	-0.07 (0.04)	-0.05 (0.03)	<0.001 *	39.923	0.136	<0.001 **	<0.001 **

*ANOVA main effect ($p < 0.05$). **Contrasts: pairwise comparison ($p < 0.05$). PF: plantar flexion. EV: eversion. IN: inversion. C1: cluster 1. C2: cluster 2. C3: cluster 3.

Figure 1. Joint moment mean curves in the sagittal and frontal planes of motion from the three markers clusters during the stance phase of walking.



The vertical line around 70% delimits the beginning of the heel rise. PF: plantar flexion. DF: dorsiflexion. EV: eversion. IN: inversion.

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Contralateral ankle complex kinematic compensations after unilateral tibiotalar arthrodesis

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Background: Tibiotalar (TT) arthrodesis is considered the standard treatment for end-stage TT osteoarthritis (OA) [1]. Unilateral TT arthrodesis may lead to compensatory motion of the contralateral foot and ankle. Few studies have quantified kinematics of the contralateral limb in patients with TT arthrodesis. Improved understanding of compensatory motion could aid in the development of biomechanical markers of ankle OA. The purpose of this study was to evaluate contralateral TT and subtalar (ST) kinematics in patients with unilateral TT arthrodesis and compare these results to data from healthy controls.

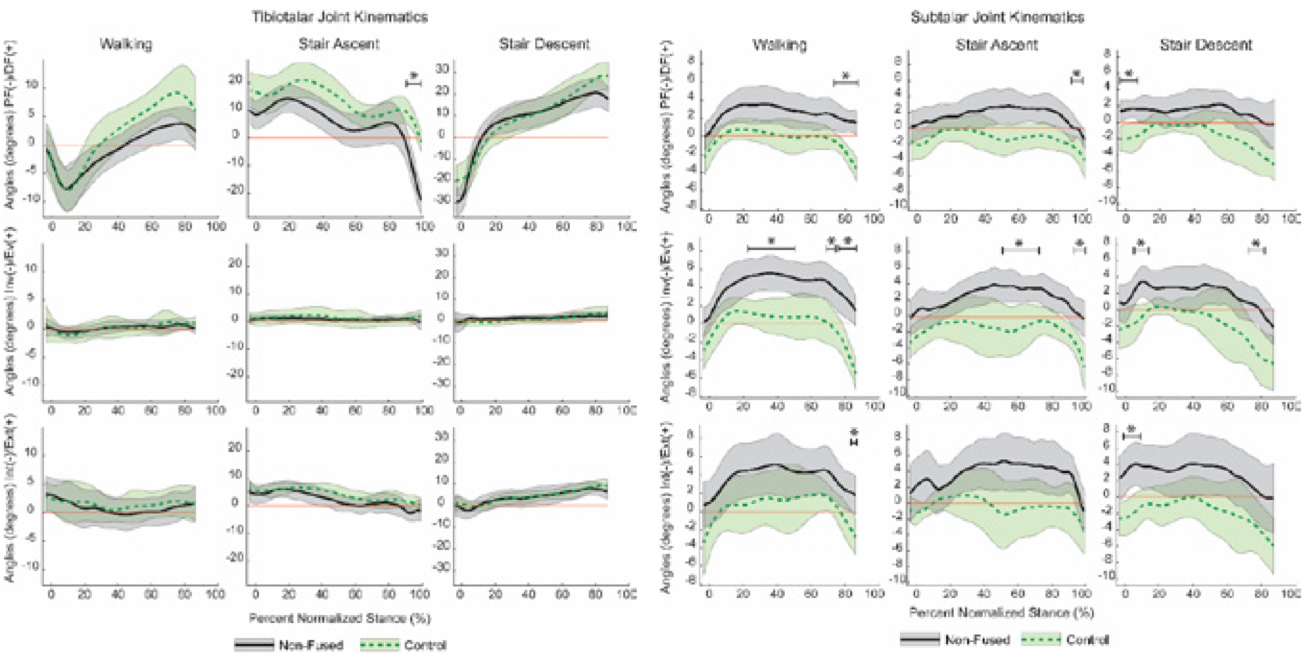
Methods: In this IRB-approved study, ten asymptomatic adults with unilateral arthrodesis (5 men; 53.2**±9.1 years; BMI 28.6±4.1 kg/m**^{2}; 5 right) and six healthy control participants (3 male; 30.9±7.2 years; BMI 23.5±3.5 kg/m^2) were studied. A validated high-speed dual-fluoroscopy system measured in-vivo TT and ST kinematics [2]. All participants performed one trial of overground walking, stair ascent, and stair descent at a self-selected speed. A computed tomography scan of the foot and ankle was segmented to define three-dimensional anatomy for the tibia, talus, and calcaneus. Markerless tracking quantified in-vivo motion of the TT and ST joints wherein kinematics were calculated using a landmark-based coordinate system and the Grood and Suntay method [2]. Confidence intervals (CIs) visualized group profiles and statistical parametric mapping evaluated differences between groups.

Results: Overall, TT kinematics for the contralateral limb were similar between the two participant cohorts with the exception of increased plantarflexion during 95-100% of push-off during stair ascent (Figure 1, significant regions denoted by an asterisk). ST kinematics for the contralateral limb demonstrated consistent findings of increased dorsiflexion, eversion, and external rotation for all activities compared to healthy control participants.

Discussion: The primary finding of this study was that the asymptomatic contralateral limb demonstrated kinematic compensations at the ST joint, but not the TT joint after TT fusion. These changes were mostly prevalent when the foot is transitioning contact with the ground (beginning and end of stance phase), and the symptomatic limb was in a transition to the swing phase of gait. The findings suggest that the ST joint of the contralateral side after TT fusion may need to increase stability to maintain balance during these gait transitions. Further evaluation of compensatory mechanisms should include co-variate analyses of age, speed, and whole-body kinematics.

Clinical Relevance: Tibiotalar arthrodesis leads to compensatory motion on the contralateral limb which may lead to long-term adoption of detrimental movement strategies, thereby potentially leading to joint degeneration or pain.

Figure 1. TT (left) and ST (right) kinematics for walking, stair ascent and stair descent. Regions of significant difference noted with *. Contralateral limbs (Non-fused grey with solid black mean) and Control limbs (Green with dashed mean) shown as 95% CIs.



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Conversion of calcaneus angle of hindfoot view into stance position angle

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Calcaneus angle (the angle between vertical sagittal plane and calcaneus bisection), is measured by X-ray to distinguish Pes Rectus, Pes Planus and Pes Cavus in clinical [1]. In the X-ray measurement of calcaneus angle, the X-ray tube tip is usually inclined 20° from the horizon for better discrimination of calcaneus, which is called hindfoot alignment view [2]. The inclination results in the error of X-ray based calcaneus angle compared to the actual stance position angle. Therefore, a conversion algorithm is required to get the actual calcaneus angle from the X-ray. The aim of this study is the development and validation of a conversion algorithm.

X-ray (Vidix 2, JW medical Inc. Korea) was used with settings of 70 kV, 100 mA, 125 ms. Tube tip was tilted 20° and the film cassette was placed at 150 cm from the tube tip on the projection line. A conversion algorithm was developed by using trigonometrical functions and Pythagorean theorem. Two models were developed with the calcaneus angle of 30° and 45° for the validation of the algorithm. The model was positioned 22 cm, 24 cm, 26 cm, 28 cm anterior from the cassette considering the foot length. Figure 1 shows two angles (before and after conversion) in comparison with the true angle of the model. The mean error of the converted angle (30° : 29.81 ± 0.023, 45° : 44.91 ± 0.07) was significantly smaller than that of the non-converted one (30° : 32.04 ± 0.1, 45° : 47.04 ± 0.23) ($p<0.001$). The results indicate that the angles from hindfoot alignment view needs to be converted for better accuracy.

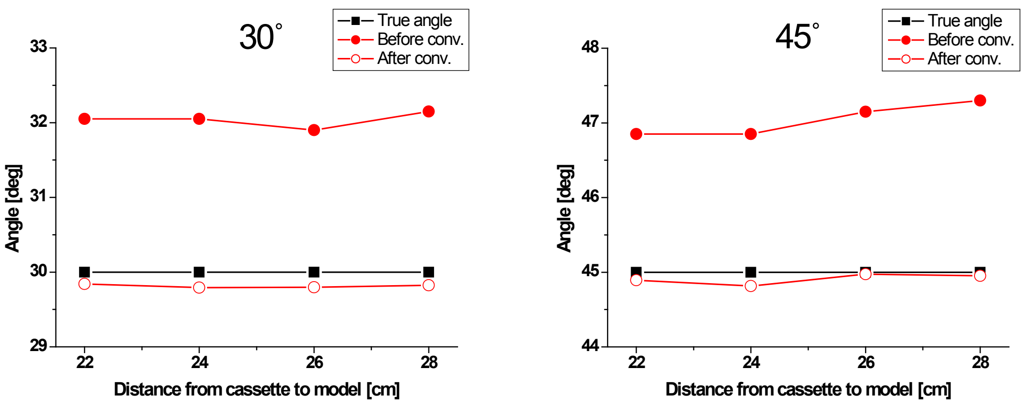

Figure 1. Comparison of calcaneus angles from X-ray and from conversion algorithm.

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Correlation between pain, functionality and lower limb muscle strength in women with patellofemoral pain and excessive calcaneal eversion

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Introduction. Patellofemoral pain (PFP) is the most common cause of knee pain in physically active young women [1]. Excessive calcaneal eversion has been related with PFP [2]. Calcaneal eversion leads to foot over-pronation, resulting in excessive internal tibial and femoral rotation, which may lead to lateral patellofemoral stress increase. This stress increase may be related with increased PFP. Decreased inversion (INV) strength may be responsible for the excessive calcaneal eversion, and increased pain and decreased INV muscle strength may lead to decreased functionality. However, it is not clear if, and how, these three outcomes are related. Therefore, the purpose of this study was to investigate the relation between pain, functionality and INV strength in women with PFP.

Methods. Thirty women (18-40 years of age) with PFP and excessive calcaneal eversion (measured as calcaneal valgus greater than six degrees at a relaxed bilateral standing position [2]) participated in the study (University Ethics Committee approval number: 2.809.328). Muscle strength was measure with a hand-held dynamometer (Microfet 2) that was fixed by a belt to the handlebar of a glass suction cup placed on the examination room floor. INV muscle force (in kilogram-force, normalized by body mass), pain scores (measured with a numeric rating scale), and functionality (measured with the Kujala Questionnaire [3]) were obtained. Correlations between pain, functionality, and INV muscle strength were obtained through Pearson correlation analysis (significance level - $p<0.05$). Correlation coefficient was classified as negligible (0.1-0.3), low (0.3-0.5), moderate (0.5-0.7), high (0.7-0.9) and very high (0.9-1.0).

Results. There was no correlation between pain and INV strength ($r=-0.255$; $p=0.174$), whereas functionality showed a low positive correlation with INV strength ($r=0.398$; $p=0.0295$), and a moderate negative correlation with pain ($r=-0.599$; $p=0.000474$).

Discussion. As expected, the higher the pain, the smaller the functionality in women with PFP. In addition, the higher the INV strength, the higher is functionality. Previous experts' clinical experience indicates an effect of distal exercises in PFP treatment [4]. Our results seem to support this idea that a distally oriented treatment program is adequate for PFP patients' rehabilitation.

Relevance: Although pain was the main factor that decreased functionality, strengthening the INV muscle group may reposition or re-align the entire limb, which may decrease PFP. Although PFP may have several determining factors and/or mechanisms, INV muscle strengthening should be included in rehabilitation programs of PFP patients with pronated foot.
Trial registration: Clinical Trials (NCT03663595).

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Correlation between stabilometry and history of sprains in professional volleyball athletes

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Volleyball is a sport played worldwide (Santini, 2008). Professional athletes in this sport are subject to injuries on the shoulders, knees and ankles, ankle sprains being the most frequent injury, compromising the team's performance during the championship (Tirabassi, 2020; Herzog et al, 2019).

Studies with the objective of preventing sprains have been carried out with focusing training and game play, demonstrating that the inclusion of proprioceptive exercises helps preventing sprains, even in athletes with no previous history of injuries (Rivera et al, 2017; Herzog et al, 2019; Grassi et al, 2017).

However, ankle sprains remain the most recurrent injury in volleyball athletes, and other factors seem to predispose the athlete (Grassi et al, 2017). Study by Tiloca et al. (2014) related the athletes' longitudinal plantar arch to the incidence of sprains was inconclusive, and a study by Vedran et al. (2009) relating strength and range of motion showed that athletes with greater strength of plantar flexors and less range of motion in dorsiflexion are predisposed to sprains. Aiming on ankle stability, Amiri et Kearney (2019) correlated the amplitude of oscillation of the COP (body center of pressure) with ankle stiffness, and concluded that the greater the postural sway in the anteroposterior direction, the greater the ankle stiffness for balance control.

Based on these studies, we propose to investigate the dynamic balance of volleyball athletes, before and after the championship season, correlating their history of ankle sprains.

Twelve professional volleyball athletes were evaluated at the beginning of the championship's training and games, observing the following parameters: history of sprain in the last 5 years, gait (neutral, pronated or supinated), COP's amplitude in the anteroposterior direction for each foot.A digital camera, Baropodometer and Kinesis software were used for data collection. As a result, we found that all athletes have a neutral step, and that 25% of them did not report a history of ankle sprain in the last 5 years. 67% of the remainder had a history of bilateral sprain. The mean COP oscillation was 2.97 cm for the right foot and 3.51 cm for the left foot. 3 athletes presented values above the average bilaterally, 2 of which did not report a history of sprain. This study will continue at the end of the championship, for comparison. We expect to observe the occurrence of sprains and to correlate with the COP data.

Correlation between the passive mechanical properties of the midfoot joint complex and the segmented foot kinetics during walking

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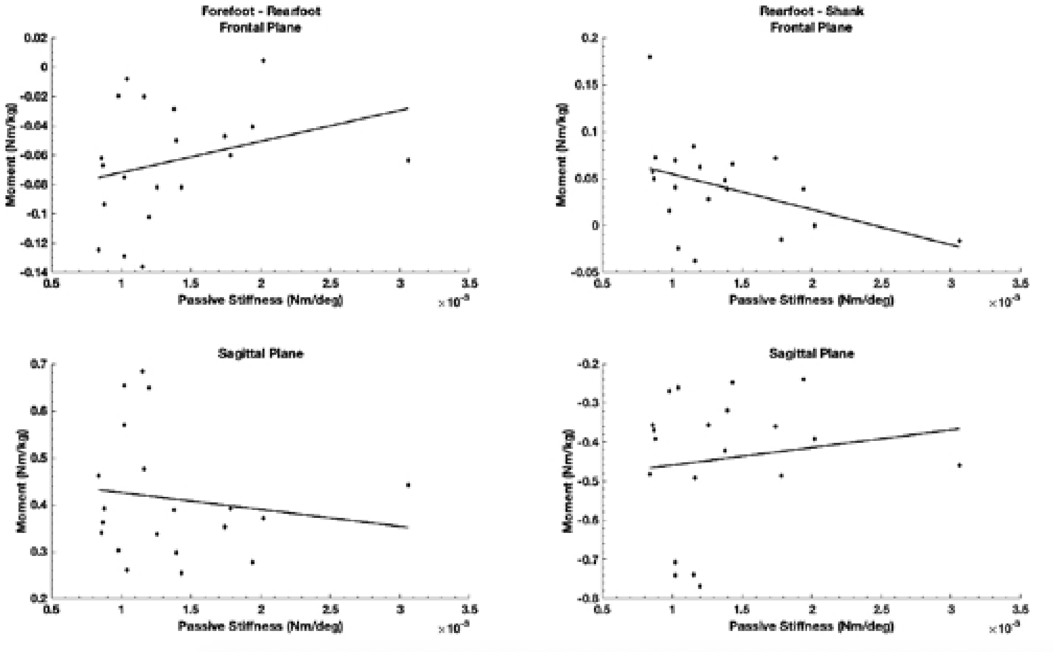
Several pathologies in the lower limbs, as fasciitis plantaris, knee osteoarthritis and trochanteric bursitis can be related to altered foot kinetics. Also, the performance of athletes during running, jumping, landing can be affected by the functioning of the foot. Thus, the aim of the present study was to investigate the correlation between a clinical measure of the midfoot joint complex's passive mechanical properties and the forefoot – rearfoot and rearfoot – shank kinetics during the propulsion phase of walking. Twelve females and eight males participated in this study (24.6 ± 4.9 years, 64.9 ± 12.1 kg and 167.3 ± 8.3 cm). The mechanical resistance to forefoot inversion relative to rearfoot was measured using the Foot Torsimeter(1, 2), which represents the mechanical resistance of the midfoot joint complex (MFJC). Passive stiffness was estimated as the average of the instantaneous slope of the torque-angle time-series measured through the Torsimeter, using the 4^{th} order polynomial method (3) between 20° and 25°. Next, each participant walked at self-selected speed on an 8-m walkway for five valid trials. kinetic data were recorded using two force plates (OR 6-7, 1200Hz, AMTI, USA) arranged inline 2-mm apart from each other positioned at the center of the walkway. MFJC's and ankle's kinetics during the stance phase of walking were computed in the software Visual 3D (C-Motion Inc, Rockville, USA), filtered with a 4^{th} order Butterworth low-pass filter at 15Hz. The joint moment (mean value in Nm/kg) was computed during the midstance phase of walking in the sagittal and frontal planes. The intraclass correlation coefficient revealed a positive and moderate correlation between the passive stiffness and the forefoot – rearfoot moment (ICC = 0.53, p = 0.016) and a negative and moderate correlation between the passive stiffness and the rearfoot – shank moment (ICC = -0.50, p = 0.025), both in the frontal plane. No significant correlation was found for the sagittal plane. These results are shown in table 1 and figure 1. Previous studies have demonstrated that the MFJC's passive properties measured with the Foot Torsimeter are related to the forefoot – shank alignment (1) and to the amount of foot pronation during gait (2). In addition, the present results also revealed that the MFJC's passive mechanical properties reflect partially the behavior of the segmented foot kinetics during the midstance of walking in the frontal plane.

Table 1. Correlation between the MFJC's passive stiffness and the segmented foot kinetics

Joint	Plane	*ICC*	*p*
Forefoot – Rearfoot Moment (Nm/kg)	Frontal	0.53	0.016*
	Sagittal	-0.32	0.163
Rearfoot - Shank Moment (Nm/kg)	Frontal	-0.50	0.025*
	Sagittal	0.33	0.149

*** p<0.05. ICC: intraclass correlation coefficient.**

Figure 1. Scatter plots of the passive stiffness versus the forefoot – rearfoot and rearfoot – shank moments.



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Correlation of First Metatarsal Sagittal Alignment with Clinical and Functional Outcomes after the Lapidus Procedure.

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Introduction

Lapidus procedure (LP) for hallux valgus (HV) requires an adequate control of the first metatarsal (1M) in the sagittal plane to avoid 1M dorsiflexion. Clinical and functional impairment, including transfer metatarsalgia can occur[1]. This study correlated pre- and postoperative measurements of 1M sagittal alignment with clinical and functional outcomes, and transfer metatarsalgia.

Methods

We included 29 patients (36 feet) with a follow-up of 20 (range, 6-51) months and age of 48.33 (range, 18-73) years who underwent the LP. Demographic data is summarized in Table 1. Radiographic analysis of 1M sagittal alignment was based on the first metatarsal declination angle (FMDA) and Meary Angle (MA) (Figures 1) [2]. Intermetatarsal angle (IMA) and hallux valgus angle (HVA) were also measured to evaluate HV correction. Clinical and functional outcomes were assessed with the Visual Analogue Scale (VAS) for pain, the American Orthopaedic Foot and Ankle Society (AOFAS) Scale, the Lower Extremity Functional Scale (LEFS) and the Short-form 12 (SF-12) health survey. SF-12 is divided into physical and mental health composite scales (PCS-12 and MCS-12, respectively). Transfer metatarsalgia diagnosis was based on the clinical exam.

Results

Significant changes in 1M sagittal alignment was observed in the FMDA but not in MA. FMDA was 21.07 (range, 11.64 to 30) degrees and the postoperative was 18.58 (range, 5.03 to 31) degrees ($p<.001$). There was a significant correction of HV ($p<.001$) in the IMA and HVA (Table 2). It was observed a significant improvement in all questionnaires (p.<001), except for MCS-12 ($p=.950$) (Table 3). FMDA was shown to be directly correlated with PCS-12 and LEFS ($p=.05$ and $p=.05$, respectively). Based on this correlation, a quartile distribution was performed, creating four different groups considering the FMDA values and PCS-12 ($p=.04$) and LEFS ($p=.031$) scores. With a multiple comparison test, it was observed that groups 3 and 4, which comprises patients with 1M sagittal alignment between 5.9 degrees of plantarflexion and 3.2 of dorsiflexion, presented better outcomes in the PCS-12 scores. While in the LEFS questionnaire, better results were found in group 4, with 1M sagittal inclination between 5.9 degrees of plantarflexion and 0.5 of dorsiflexion (Table 4). None of the patients presented transfer metatarsalgia.

Conclusion

We concluded that overall, the LP produces clinical and functional improvement and better outcomes are likely to be obtained in a FMDA interval between 5.9 degree of 1M plantar flexion and 3.2 of dorsiflexion. Therefore, we believe that even with some degree of 1M dorsiflexion, patients tend to improve considerably.

Patients (feet)	Age	Gender	Side	BMI	Mean Postoperative Time (months)
29 (36)	48.33 (range, 18-73)	25F:4M	20L:16R	24.98 (range,19.13-33.2)	20 (range, 6-51)

Table 1. Demographic data.
Abbreviations: BMI, body mass index; F, female; M, male; L, left side; R, right side.

	FMDA (95% CI)	MA (95% CI)	RML (95% CI)	HVA (95% CI)	IMA (95% CI)
Preoperative	21.07 (20.06 to 22.08)	-3.27 (-5.64 to -0.89)	-3.06 (-2.43 to -3.69)	34.7 (33 to 36.40)	16.85 (16.18 to 17.53)
Postoperative	18.58 (17.18 to 19.99)	-4.72 (-6.69 to -2.76)	-5.34 (-4.72 to -5.97)	13.52 (11.67 to 15.36)	9.7 (8.88 to 10.52)
p	<.001*	.118	<.001*	<.001*	<.001*

Table 2. Pre- and postoperative radiographic measures in the lateral and anteroposterior weightbearing radiographic foot views.
Abbreviations: CI, confidential interval; FMDA, first metatarsal declination angle; MA, Meary angle; RML, relative first metatarsal length; HVA, hallux valgus angle; IMA, intermetatarsal angle.
*Significance at p<.05.

	VAS (95% CI)	AOFAS (95% CI)	LEFS (95% CI)	PCS-12 (95% CI)	MCS-12 (95% CI)
Preoperative	8.19 (7.62-8.76)	40.41 (36.89-43.94)	54.22 (48.87-59.56)	40.42 (37.22-43.61)	50.11 (46.39-53.83)
Postoperative	1.41 (0.8-2.02)	85.25 (81.29-89.2)	73.52 (71.34- 75.7)	53.27 (51.71-54.83)	51.50 (48.25-54.74)
p	<.001*	<.001*	<.001*	<.001*	.95

Table 3. Pre- and postoperative clinical and functional outcomes.

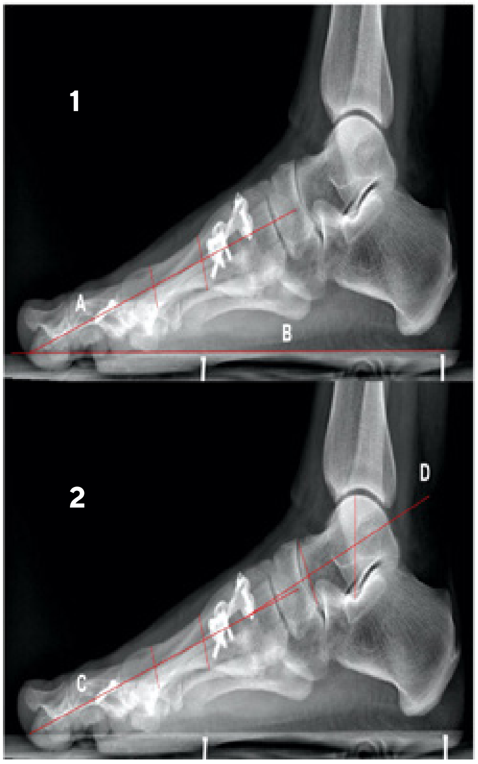
Abbreviations: CI, confidential interval; VAS, visual analogue scale for pain; AOFAS, american orthopaedic foot and ankle society hallux metatarsophalangeal-interphalangeal scale; LEFS, lower extremity functional scale; PCS-12, SF-12 physical composite scale; MCS-12, SF-12 mental composite scale.

*Significance at p<.05.

Groups	FMDA	N	LEFS (95% CI) Δ Pre - Postoperative	PCS-12 (95% CI) Δ Pre - Postoperative
1	-8.95 to -4.95 degrees	9	16.83 (3.99 – 28.23)	15.67 (1.9 – 19.17)
2	-4.95 to -3.2 degrees	9	15.11 (-0.17 – 28.17)	14.28 (-1.2 – 17.02)
3	-3.2 to -0.5 degrees	9	14.61 (4.29 – 20.37)	16.94 (6.91 – 18.05)
4	-0.5 to 5.9 degrees	9	27.44 (23.95 – 45.60)	27.11 (14.38 – 26.60)

Table 3. Kruskal Wallis test recognized the quartile distribution as four different groups, regarding the relationship of FMDA values with PCS-12 (p=.04) and LEFS (p=.031) scores. With the Dunn multiple comparison test, it was observed that groups 3 and 4 presented better outcomes in the PCS-12 scores. While in the LEFS questionnaire, better results were observed in group 4.

Abbreviations: CI, confidence interval; N, number of feet; FMDA, first metatarsal declination angle; LEFS, lower extremity functional scale; PCS-12, SF-12 physical composite scale.



Figures 1. (1) First metatarsal declination angle (FMDA) and (2) Meary angle (MA) measurements in the weightbearing lateral radiographic foot views were used for 1M dorsiflexion assessment. The references for the FMDA were an angle between a line of the long axis of the 1M (*line A*) and another line parallel to the ground (*line B*). Decrease of the FMDA indicates that there was a 1M dorsiflexion. The references for the MA were an angle between a line of the long axis of the 1M (*line C*) and another line of the long axis of the talus (*line D*). Normally, positive values indicate pes cavus, while negative values indicate pes planus.

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Coverage and Congruity Analysis of the Articulating Surfaces in the Ankle Joint

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Introduction

Various foot pathologies affect the articular surface-to-surface geometrical interaction at the ankle. This interaction is characterized primarily by the surface coverage and level of congruity defined as the uniformity of the space distribution across the covered region. These were analyzed in this study focused at the ankle and subtalar joint between normal and valgus feet. It is hypothesized that deformities, presence of osteoarthritis or motion away from the neutral position, would result in decreased of coverage and congruity. Furthermore, this can be used as a definition of ankle neutral, which is still under controversy [1, 2].

Methods

3D renderings of the Tibia, Fibula, Talus and Calcaneus were produced from CT scans. The ankle joint articular surfaces were identified on the superior aspect of the talus (Fig 1a). The subtalar articular surfaces were identified on the inferior aspect of the talus (Fig 1b). For each sub-region, distance mapping describing the surface-to-surface distance distribution were displayed as color-coded maps (Fig. 2) [3]. From this, coverage was calculated as the part of the articular cartilage region on the bone covered by the contralateral bone. Congruity, as the ratio between the standard deviation of the distance map and the average distance within the covered region.

Results

The articulating surfaces (talar dome and medial surface) of the ankle joint with valgus deformities show a 20% decrease in coverage (Figure 2.2-3), while the lateral surface shows a 5% decrease in coverage (Figure 2.1). The articulating surfaces of the subtalar joint show a decrease of around 12% in coverage for all its surfaces (Figure 2.4-6). The talar dome also shows a 30% decrease in congruity while the lateral and medial surfaces show a 5% decrease. Lastly, specimens with valgus deformities show almost a 20% decrease in congruity for the subtalar joint compared to healthy specimens.

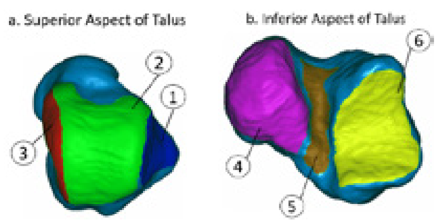

Figure 1a: Articulating Surfaces of the Ankle Joint, **1b**: Articulating Surfaces of the Subtalar Joint

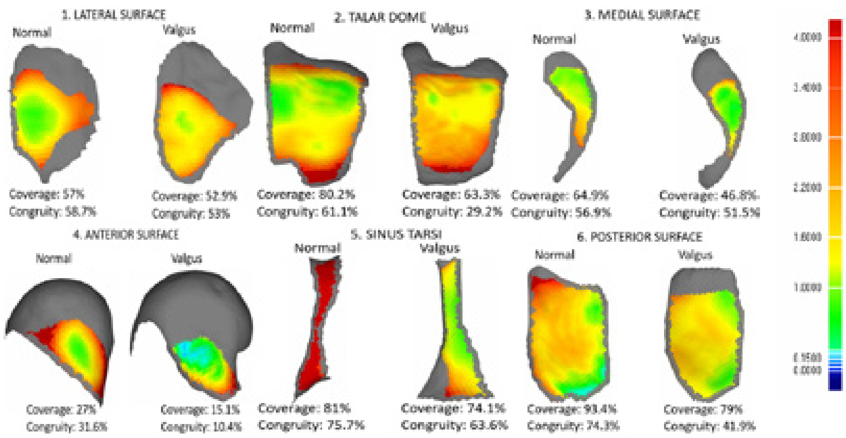

Figure 2: Color-coded maps representing: **(1-3):** distance from superior aspect of talus to the tibia and fibula, **(4-6)**: inferior surface of talus to calcaneus

Discussion and Conclusions

Overall, the covered region projected on one surface will get displaced due to a deformity, its percentage decreases. The covered percentage compared to the whole articulating surface does not shift by a large number. However, congruity is analyzed at the covered region which is shifted due to the deformity and is therefore much less than the maximum value in a normal specimen.

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Deficit of vibration sense in the lower limb of children and adolescents with Charcot-Marie-Tooth disease

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Introduction: The reduction or loss of vibration sense is an important clinical manifestation in Charcot-Marie-Tooth disease (CMT) present since childhood [1]. Objective data about this clinical manifestation in childhood and adolescence are scarce, compromising the knowledge about the natural history of the disease. The objective of this study was to compare the vibration sense of the lower limb of participants with and without CMT.

Methods: Cross-sectional study (CAAE n° 86153918.9.0000.5440) comprised of CMT (n=32) and Control (n=32) groups. These groups were divided into subgroups: CMT child (CMT-ch; n=12), CMT adolescent (CMT-ad; n=20), Control child (Control-ch; n=12) and Control adolescent (Control-ad; n=20). The vibration sense assessment used the 128 Hz graduated Tuning Fork equipment (Rydel Seiffer; Kawe; Germany), which has a semi-quantitative scale ranging from 1-8 points (the higher the score, the lower sense deficit) [2,3]. The hallux, first metatarsus, medial malleolus, and tibial tuberosity were evaluated [3,4]. Statistical analysis used the SAS program (version 9.3; SAS Institute, Inc.; Cary, NC) and R Core Team (2016). The t-test for independent samples ($p<0.05$) verified the anthropometric differences between the CMT and Control. To compare the vibration sense between groups and subgroups, the general linear mixed models were used, in which a confidence interval that does not include zero suggests evidence difference.

Results: There was no significant difference between CMT and Control concerning the anthropometric data ($p<0.05$) (Table 1). The vibration sense showed reduction in all the evaluated points of the CMT and CMT-ad when compared to their controls (Table 2). The most proximal evaluated points as the tibial tuberosity and the medial malleolus did not show evidence difference between CMT-ch and Control-ch (Table 2).

Discussion: The known pediatric data of vibration sense in CMT are part of the CMT Pediatric Scale (CMTPedS) [4,5,6], in which the score ≤5 indicates decreased vibration sense[4]. In our study, although there was no evidence difference in the vibration sense of all evaluated regions in the children with CMT and despite not be considered relevant by CMTPedS, this result should be explored from the clinic and rehabilitation perspectives.

Relevance: This is the first study to characterize vibration sense in children and adolescents with CMT separately. Our data reinforce the importance of monitoring vibration sense since childhood and suggest that therapeutic strategies be adopted for this population, as well as those adopted for other morbidities [7,8], however considering the specificities of the CMT children and adolescent.

Table 1 – Anthropometric data of the characteristics of participants and subtypes of CMT.

	Sex		Age (years) Mean (SD)	Weight (kg) Mean (SD)	Height (cm) Mean (SD)	Subtypes of CMT			
	Female	Male				1A	2A	X	Undefined
CMT (n=32)	15	17	12.93 (2.48)	51.15 (12.72)	156.16 (10.52)	21	3	3	5
Control (n=32)	15	17	12.78 (2.59)	48.44 (14.09)	156.84 (15.54)	-	-	-	-

Table 2- Comparisons between vibration sense values at the different anatomical points

Anatomical points	CMT (n=32) Mean (Min-Max)	Control (n=32) Mean (Min-Max)	Mean difference (95%CI)	CMT- ch (n=12) Mean (Min-Max)	Control-ch (n=12) Mean (Min-Max)	Mean difference (95%CI)	CMT- ad (n=20) Mean (Min-Max)	Control- ad (n=20) Mean (Min-Max)	Mean difference (95%CI)
Hallux	3.91 (0.00-6.66)	6.66 (4.33-8.00)	-2.74 (-3.54;-1.95)*	5.03 (2.70-6.67)	6.81 (4.67-8.00)	-1.78 (-3.02;-0.54)*	3.24 (0.00-6.67)	6.57 (4.33-8.00)	-3.32 (-4.28;-2.36)*
First Metatarsus	4.43 (0.00-8.00)	6.63 (4.66-8.00)	-2.42 (-3.22;-1.61)*	5.33 (2.67-7.00)	6.85 (5.33-8.00)	-1.52 (-2.76;-0.28)*	3.76 (0.00-8.00)	6.50 (4.67-8.00)	-2.98 (-3.95;-2.00)*
Medial Malleolus	4.31 (0.00-7.66)	6.17 (4.83-8.00)	-1.85 (-2.65;-1.05)*	5.30 (3.00-7.00)	6.54 (5.00-8.00)	-1.23 (-2.47;0.00)	3.71 (0.00-7.67)	5.94 (4.83-8.00)	-2.22 (-3.18;-1.26)*
Tibial Tuberosity	4.64 (1.33-7.66)	5.65 (3.83-8.00)	-1.00 (-1.80 -0.20)*	5.53 (2.70-7.00)	5.83 (4.33-8.00)	-0.30 (-1.53;0.93)	4.11 (1.33-7.67)	5.54 (3.83-8.00)	-1.42 (-2.38;-0.46)*

CMT-ch = child CMT; CMT-ad = CMT-adolescent; Control-ch = Child Control; Ad-control = Adolescent control; * = significant difference when compared to their respective control group ($p < 0.05$).

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Design of dynamic foot function models: a finite element and machine learning approach

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Introduction: A wide range of methods to classify foot types have been documented for static and dynamic measurements [1] with the aim of displaying some characteristics that may be related to pathomechanical function. Among these foot types, the flatfoot is a common foot deformity characterized by collapsing of the medial arches and hindfoot eversion. In order to investigate the behavior of abnormal foot function or clinical treatments, numerical simulations with Finite Element (FE) models are widely used [2]. Nevertheless, because of the complex structure of the foot and great variability among patients, the customization of these models is a real challenge for the development of personalized and effective therapeutic solutions. This study proposes a method based on simplified foot FE simulation in walking condition and machine learning tools to design and predict different foot function patterns.

Method: A FE foot model was developed based on literature review and dynamically validated according to vertical ground reaction force, plantar pressure and ankle kinematic during the stance phase of a walking (figure 1 A)). Four variable parameters related to the flatfoot pathology including, mid-tarsal and subtalar joint laxity, subtalar joint medial-lateral position and fascia stiffness, were integrated in a reduced Design of Experiments (DOE) of 28 simulations. The center of pressure (COP) path was extracted for each simulation and normalized (figure 1 B)). A machine learning process was also applied to identify the parameters effects on the medial-lateral excursion of the COP path and a real-time predicted model was proposed and validated with 4 more random parameter sets.

Result: The proposed FE foot model demonstrates a good sensitivity to the selected parameters with difference in the COP medial-lateral excursion from 8,8mm to 21,8mm (figure 1 C)). Moreover, the sensitivity analysis indicates that the medial-lateral position of the subtalar joint and the mid-tarsal joint laxity are the most significant contributors to the flatfoot function (decrease of the COP excursion). The comparison of COP paths from the predicted model and validation simulations shows a good accuracy.
Conclusion: The current study provide some numerical evidences that support the concept of subtalar joint rotational equilibrium and the key role of the joints structure on the dynamic foot function. To authors' knowledge, it is the first time that machine learning tools were used with a FE foot model to design dynamic foot functions.

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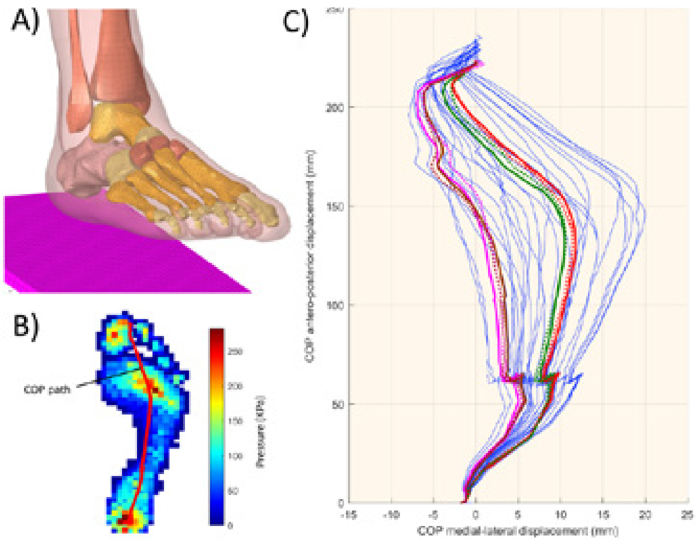

Figure 1. FE Foot model A), Plantar pressure and COP path for one simulation B), DOE results for the COP path during the stance phase of gait (solid blue lines = COP path of all simulations, solid color lines = predicted COP path for new sets of parameters, dotted color lines = COP path of simulations with the new sets of parameters) C)

Design, mechanical characterization and functional evaluation of novel custom AFOs for drop-foot patients

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Background

Ankle Foot Orthoses (AFO) can be prescribed to address functional impairment of the main ankle dorsiflexor muscles in drop-foot patients. Additive manufacturing technologies allow to produce custom AFOs, designed from 3D scans of patients' morphology [1,2], with improved fit and comfort. In this study, an original custom AFO was designed and produced via Selective Laser Sintering (SLS) using a lightweight composite material. Aim of this study was to assess the mechanical properties of the custom AFO via an original experimental setup and FEM analysis replicating gait biomechanics.

Two drop-foot patients (67/80 years; 83/96 kg; 1.80/1.95 m) volunteered in the study. The affected foot and shank of each patient were 3D scanned and the STL files were imported in Blender (Blender Foundation, Amsterdam) to design the custom AFOs. These were printed via SLS using a fiber-glass reinforced polyamide-based composite material (Windform GT®, CRP Technology, Modena). A servo-hydraulic testing machine (MiniBionix 858, MTS) was used to assess the stiffness of the custom AFOs and of standard polyethylene Molla di Codivilla (Ottobock) (Figure 1a). FEM analysis was used to test the AFOs in the same conditions replicating the midstance phase of gait (Ansys®, version 19.2) (Figure 1b). Gait analysis of patients wearing the AFOs was assessed via the IOR-gait protocol [3]. The perceived comfort was assessed via a 0-10 VAS scale.

Results

The FEM-estimated stiffness of the two AFOs were 0.19 and 0.27 N*m/deg, comparable to that of same-size Codivilla (0.28 N*m/deg). The mean Von-Mises stress in the custom AFOs critical region was about 20 MPa, lower than the yield strength of the material (51 MPa). Both subjects walked faster and the ankle maximum dorsiflexion in the swing phase was larger while wearing the custom AFO with respect to the no-AFO condition. The custom AFO was perceived more comfortable (9.7 vs. 5.8) and providing greater elastic return (9.8 vs. 7.5) than the Codivilla.

Conclusion

Custom AFOs are feasible via additive manufacturing and can be used to improve patients' gait and quality of life. The novel SLS-printed custom AFO has proved to be more comfortable than a standard off-the-shelf AFO and has resulted in faster gait speed and longer stride length. The present mechanical and FEM analysis protocols will be implemented on a larger population of drop-foot patients and will allow customization of the AFO design with respect to subject-specific functional demand and level of impairment.

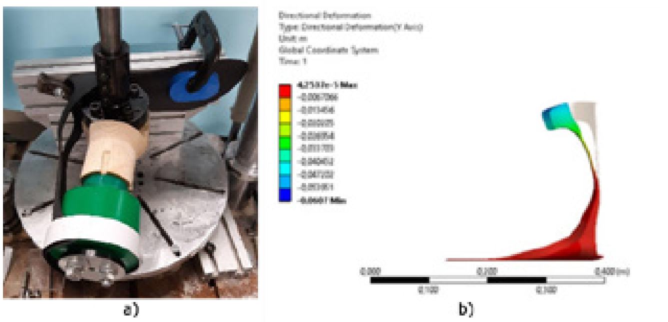

Figure 1. a) Bench testing setup to assess the mechanical properties of the custom AFO; b) FEM analysis showing color-map of displacements for 15 deg of flexion.

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Development and Validation of a Multi-Segment Foot Model using Biplanar Videoradiography.

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Background: Accurately measuring the function of musculoskeletal structures in the foot is important for our understanding of foot function, human locomotion and lower limb pathologies. Today, a combination of optical motion capture (optMocap) and multi-segment foot modelling is used to investigate the function of the foot. The accuracy of these foot models are relatively low (differences range between 3 to 8° compared to bone pin data [1]) and few are capable of predictive simulations. Therefore, the aim of this project was to develop a multi-segment foot and ankle model, and to validate the kinematic outputs using biplane videoradiography (BVidRad).

Methods: A 6-segment model was developed consisting of the tibia, talus, calcaneus, midfoot, forefoot, toes with a total of 7 degrees of freedom (DoF) in OpenSim [2]. Motion between segments were constrained such that all joints except for the ankle were modelled as a revolute joint with a single oblique axis as documented in the literature [3]–[5].
Seven healthy participants (5 males; 166 ± 14 cm, and 77 ± 13 kg) walked and ran barefoot as optMocap and BVidRad were simultaneously recorded. The Rizzoli marker set [6] was used to scale the foot model and compute joint kinematics using inverse kinematics analyses. Segment local coordinate systems were aligned to the lab coordinate system at 30% of stance. To benchmark the performance of the model, the similarity between the model and BVidRad data were assessed using one-dimensional analysis (linear fit modeling and root mean square (RMS) differences) across coordinates planes and compared to a typically implemented model with 6-DoF between each segment (6-DoF model).

Results: The Joint Constrained (JC) model demonstrated significantly smaller mean RMS differences across all gaits, planes and comparable joints (ankle, midtarsal and tarsometatarsal joints) compared to the 6-DoF model (Table 1). The mean R^2 illustrated a moderate linear relationship of both models to BVidRad data [JC: 0.48 (0.32 - 0.96); 6-DoF: 0.45 (0.32 - 0.96)]. The JC model demonstrated significantly smaller RMS differences in the sagittal plane compared to the 6-DoF model although errors in the frontal and transverse planes were comparable.

Discussion and Conclusion: The JC model was capable of accurate musculoskeletal analyses of human walking and running. The limited DoF of the model is well suited for predictive simulations. This model has potential for use in clinical gait analysis or for more complex simulations of the interaction of the foot with assistive devices or footwear.

Table 1. RMS errors (range) of the joint constrained and 6-DoF model compared to biplanar videoradigraphy across the stance phase of gait.

	Joint Constrained Model	6-DoF model	p-value
Mean (all planes)	2.74° (1.29 - 4.46)	3.17° (1.3 - 5.27)	≤ 0.01
Sagittal Plane	1.68° (1.22-2.23)	3.05° (1.3-5.27)	≤ 0.01
Frontal Plane	3.09° (2.36-3.67);	3.17° (2.91-3.55)	0.74
Transverse Plane	3.66° (3.18-4.46)	3.28° (2.73-4.22)	0.13

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Differences in mechanical skin properties as a compensatory mechanism of sensory impairment in Diabetes patients?

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Introduction: Patients with diabetic neuropathy (DPN) show increased vibration perception thresholds (VPT). However, there is no difference between Diabetics without DPN (DM) and healthy subjects (CG) [1]. Furthermore, plantar skin properties change with the onset of Diabetes [2]. This study compares the biomechanical skin properties (hardness, thickness) and the VPT between three different study groups (DM, DPN, CG).

Methods: 66 subjects (CG: n = 33, 56.3 ± 9.9 yrs; DM: n = 20, 53.3 ± 15.1 yrs; DPN: n = 13, 61.0 ± 14.5 yrs) participated in this study. Diabetics were divided based on fuzzy score [3]. Skin hardness was measured with a durometer and thickness by an ultrasound device. VPTs at 30/200 Hz were evaluated by a vibration exciter at two different foot locations (1st metatarsal head (MTH) and Heel).

Results: Significant differences between groups were found for VPT at both anatomical locations and for skin hardness only at the Heel (Table 1).

Table 1: Mean ± SD of VPT, skin hardness (Duro) and skin thickness (Ultra).

	Heel 200 Hz [µm]	MTH 200 Hz [µm]	Heel 30 Hz [µm]	MTH 30 Hz [µm]	Heel Duro [Shore]	MTH Duro [Shore]	Heel Ultra [mm]	MTH Ultra [mm]
CG	5.2 ±7.1§	5.8 ±8.2§	23.4 ±19.9§	15.6 ±15.0§	28.6 ±7.9*	29.1 ±14.0	0.78 ±0.17	0.72 ±0.10
DM	4.6 ±7.5#	4.6 ±8.6#	35.6 ±29.5#	20.7 ±21.6#	33.4 ±8.3	27.1 ±7.5	0.94 ±0.41	0.78 ±0.41
DPN	23.7 ±23.2§#	33.2 ±25.7§#	155.6 ±160.1§#	172.3 ±199.5§#	39.0 ±8.8*	31.3 ±8.4	0.86 ±0.40	0.71 ±0.40

*Superscripted symbols represent significant differences: * p = 0.001, § p < 0.001, # p < 0.001.*

Discussion: The mechanical skin properties in habitually barefoot healthy subjects have no influence on their VPT, though they have harder and thicker skin compared to habitually shod subjects [4]. While this hardening and thickening can be seen as a protective mechanism without impairing sensory properties, the skin of diabetics changes due to the accumulation of glycolysis products [2] and morphological modifications of the mechanoreceptors [5]. From a sensory point of view, however, it seems possible that in the progression of diabetes the body may counteract the skin mechanoreceptor changes by hardening the skin. In addition, the hardening of the skin is facilitated by the fact, that diabetics increase their impact during walking due to sensory changes that have already started. This could cause an increasing spread of vibration and therefore lead to spatial summation effects, especially at 200Hz [6]. With onset of neuropathy, the skin becomes even harder – the body's attempt to reach the remaining mechanoreceptors. However, the morphological changes and neuronal degeneration predominates [5] which causes higher VPT compared to DM and CG.

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Differences in vertical stiffness and center of mass excursion between runners with a rearfoot and forefoot strike pattern

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Introduction:
Runners exhibiting a rearfoot strike (RFS) pattern have demonstrated higher rates of injury compared to those with a forefoot strike (FFS) pattern.[1] Vertical stiffness (VSTIFF), as well as knee joint stiffness, has also shown associations with injury in runners.[2,3] A potential link between RFS patterns and injury, is that RFS runners exhibit higher stiffness during the impact phase of gait, due to a lower center of mass (COM) excursion. The purpose of this study was to compare VSTIFF and COM excursions between RFS and FFS runners.

Methods:
42 RFS and 42 FFS runners (17/25 female/male for each) who presented to a running clinic for treatment completed a gait assessment on an instrumented treadmill. Participants were given a 3-minute warm-up at a self-selected pace and then 16-seconds of ground reaction force data was collected. Peak VSTIFF and COM excursion for each stride were calculated during initial loading, approximately the first 15% of stance. Mann-Whitney U tests were performed to compare VSTIFF and COM excursion between groups. A combination of analysis of variance/covariance models were used to examine the degree to which COM excursion explained differences in VSTIFF between groups.

Results:
No significant differences in age, weight, or self-selected running speed were noted between footstrike pattern groups. Vertical stiffness was significantly higher, and COM excursion lower, in the RFS compared to FFS group (**p<0.001**; Figure 1). An analysis of variance model showed a strong main effect of footstrike pattern on VSTIFF (**F=58.9, p<0.001,** η^2=0.**42**) However, the main effect was greatly reduced (**F= 4.14, p=0.045,** η^2**=0.05**) with the addition of COM excursion as a covariate (**F= 32.6, p<0.001,** η^2=0.**29**).

Conclusions:
Our results demonstrate higher VSTIFF in RFS vs FFS runners, and COM excursions explained a large amount of the differences between groups. Higher stiffness indicates a reduced ability to attenuate the sharp increase in vertical forces during early stance. This may partially explain the increased injury incidence noted in RFS versus FFS runners.[1]

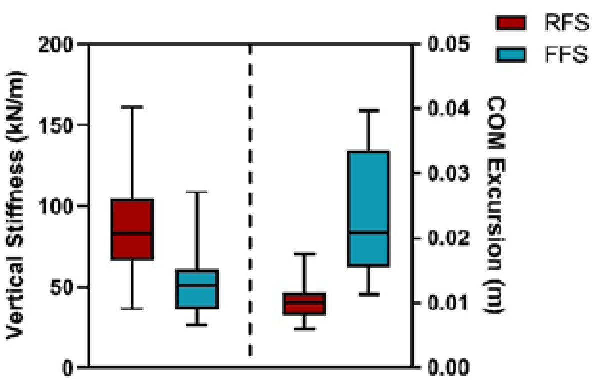

Figure 1. VSTIFF and COM excursion between RFS and FFS groups

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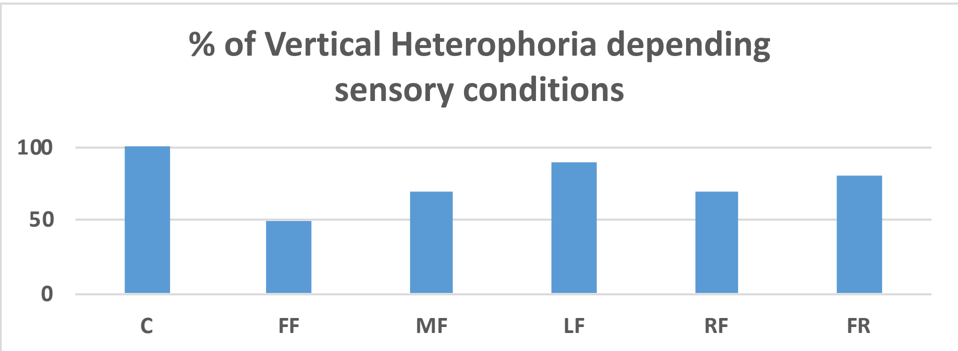
Differentiate contribution of plantar field stimulation on balance control.

Background: Human postural control is believed to be modulated by the integration of different sensory inputs including vision, vestibular, proprioception and plantar feedback. [1, 2].

To quantify sensory participation in quiet stance, foot stimulation was studied to identify plantar system contribution on balance performance and interaction with other sensory inputs [3]. Stimulations could be inserts (thin or over 3mm, [4]), insoles [5, 6], or texture [7, 8].

However, the foot sole sensitivity is not uniform from the heel to toes in anterior-posterior and lateral-medial plan [9]. The purpose of this study was to assess the effect of plantar field stimulation by texture on balance control. Method: 10 healthy subjects with Vertical Heterophoria (VH) on Maddox rod were included. The inter action in the sensory plantar reweighting after texture stimulation and the vision while assed by the reduction of VH [10]. Plantar stimulation of the foot were randomly the Full Foot (FF), Lateral (LF) and Medial (MF) dived by the axe of the feet and Rare Foot (RF) and Forefoot (FF) divided by the bimalleolar axis. Result: All conditions induce a reduction of the number of VH. Higher reduction is observed for F and the lowest for L. More reduction is obtained for M and A than L and P in each plan. Discussion: The reweighting of the stimulation by Black Pyramide influence reflexes response and balance control with reduction of the Heterophoria. This performance are depending of stimulation localisation in correspondence of FAI and SAI repartition distribution and perception threshold. SAI and FAI are respectively coupling with reflex and information of the surface [9]. MF and RF stimulations, where foot sensitivity is higher, induce the further reduction of VH than RF and FF stimulation. This reinforces the specific foot sensory implication on balance control. Practice implication: This evaluation could be use in Sensory Processing Disorders [11] and/or Dyproprioception Syndrome [10].



C: Control, FF: Full Foot, LF: Lateral, MF: Medial (MF) dived by the axe of the feet and Rare Foot (RF) and Forefoot (FF)

Clinical Registration ELMJ1/2019/APC 1605ES/2016-A01062--RCB-DM

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Digital foot health technology and diabetic foot monitoring: A systematic review

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Introduction: Where diabetic foot ulcers are concerned, a correlation between pressure and skin temperature is suspected. Early identification of the initial pathological changes of deep ulcers are difficult to observe with the current available assessment techniques, and thus it is only contributing to a minimum. The aim of this systematic review is to provide a more rigorous analysis of existing literature related to the various technologies used to read and measure both in-shoe plantar pressures, and in-shoe skin temperatures simultaneously. In addition to this, this review looked into the validity, reliability and responsiveness of such devices and explored the type and size of sensing devices, number and placement of sensors, and the statistical analysis used in studies.

Methods: A systematic review of the literature related to the topic was searched in database sources such as Medline OVID, Cochrane Library, PubMed, CONAHL, PROSPERO, and Elsevier. Outcome measures of interest included validity, reliability and responsiveness of in-shoe temperature and/or pressure mapping device used, and characteristics and quantity of sensors used, anatomical landmarks and statistical analysis used to interpret the data (Figure 1). Quality of evidence and risk of bias was evaluated using the QUADAS-2.

Results: Nineteen studies were identified and included in this review. The majority of studies used a small sample size (mean n=17) and recruited healthy participants. All studies have shown excellent validity but only a few tested for the reliability of the device. None of the studies tested for responsiveness of the device. Quality assessment results scored high risk in view of 'patient selection', 'use of reference standard' and 'applicability', and low risk in view of 'use if index test' and 'flow and timing' (Table 1).

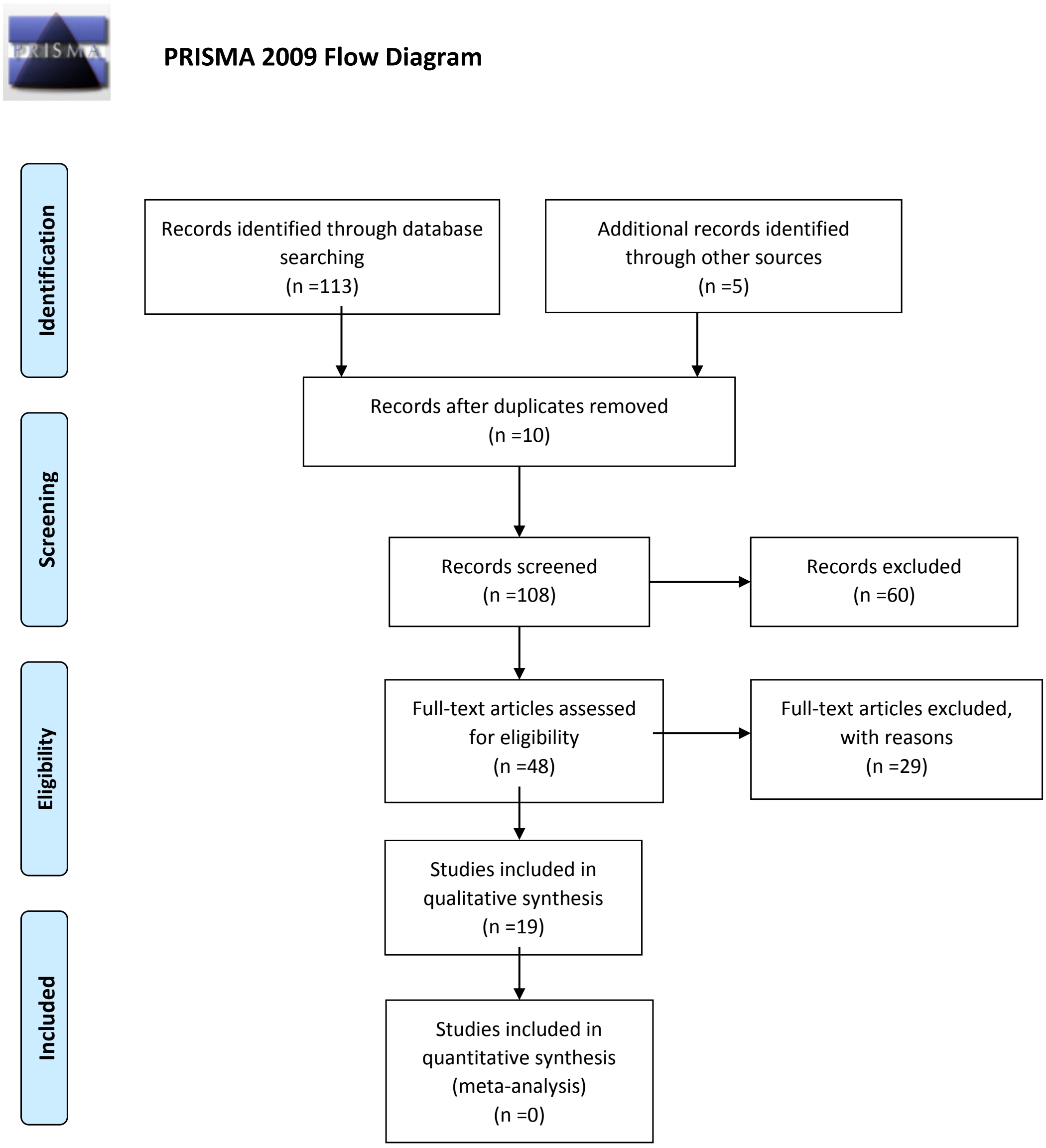
Discussion: This systematic review was first to provide a more comprehensive and rigorous analysis of existing literature related to the various technologies used to measure in-shoe temperature and in-shoe plantar pressures of the diabetic foot. Health care guidelines encourage improvement of diabetic foot care quality through the use of objective risk evaluations [1-4] because it is well proven that objective risk assessment of the diabetic foot can early identify the risk of ulceration and thus reduce ulcer development by 70% [5-7]. Despite the fact that the included studies in this review addressed the diabetic population, we expected the studies to investigate the validity and reliability of their device on participants living with diabetes mellitus rather than on healthy individuals. We had also expected to find more studies that have utilized devices that are able to measure in-shoe pressure and in-shoe temperature simultaneously. Furthermore, only six studies (out of 19) investigated the reliability of their device and that no studies were found to have investigated its responsiveness. Current evidence of a newly developed cost-effective device that is able to measure in-shoe temperature and pressure simultaneously, is not robust enough to confirm the reliability and validity of such a device. The development of a reliable and valid device would help in the early identification of ulcer development. Valid and reliable measurement of peak plantar pressures and skin temperature would give the clinician an objective risk assessment on which to base his/her clinical reasoning [2]. Thus, confirming the reliability and validity of these instruments is empirical as this would indicate that the device is indeed consistent and highly accurate in detecting the changes that are being observed [8]. This would highly encourage both clinician and patient to rely on such measurements and thus delays in obtaining adequate results are avoided leading to decreased cases of ulceration and hospitalization [9,10].

Relevance: The value of this study is that it provides a comprehensive understanding of the currently available technologies purposively developed to simultaneously measure in-shoe plantar pressures and temperature. The data outlined in this review confirms that further improvement, reliability testing and clinical validation of the developed systems is required. The type of information gathered from this review, can be useful in identifying functioning characteristics of mentioned devices to develop an innovative, low cost, reliable and valid, in-shoe pressure and temperature measuring device that can be used as an alternative to current technology to predict the risk of ulceration prior to tissue breakdown.

Table 1. Table showing the results for QUADAS-2 Quality Assessment Tool.

		Bias				Applicability		
	AUTHOR & YEAR OF PUBLICATION	**PATIENT SELECTION**	**INDEX TEST**	**REFER-ENCE STAN-DARD**	**FLOW AND TIMING**	**PATIENT SELEC-TION**	**IN-DEX TEST**	**REFER-ENCE STANDARD**
TEMPERATURE AND PRESSURE COMBINED	Morley et al. (2001)	Unclear	Low	Low	Low	High	Low	High
	Maluf et al. (2001)	Low	Low	Low	Low	High	Low	High
	Najafi et al. (2017)	Low	Low	Low	Low	Low	Low	Low
	Rescio et al. (2018)	Unclear	Low	Low	Unclear	High	Low	Low
	Rescio et al. (2020)	High	Low	Low	High	High	Low	Low
IN-SHOE PRESSURE	Ferber et al. (2013)	Low	Low	Low	Low	High	High	High
	Lee et al. (2019)	Low	Low	High	Low	High	High	High
	Najafi et al. (2017)	Low	Low	High	High	Low	Low	High
	Ostadabbas et al. (2012)	Unclear	Low	High	High	High	High	High
	Shu et al. (2010)	Unclear	Low	Low	Low	High	High	High
	Price et al. (2016)	High	Unclear	High	High	High	High	High
	Guo et al. (2012)	High	Low	High	High	High	High	High
	Wang et al. (2015)	High	Unclear	High	High	High	High	High
IN-SHOE TEMPERATURE	Reyzelman et al. (2018)	Low	Low	Low	High	Low	Low	Low
	Lugoda et al. (2018)	High	Low	High	High	High	High	High
	Sandoval-Palomares et al. (2016)	High	Low	High	High	High	High	High
	Coates et al. (2016)	High	Low	High	High	High	High	High
	Ming et al. (2019)	Low	Low	High	High	Low	High	High
	Shoureshi & Albert (2006)	Unclear	Unclear	High	Unclear	High	High	High
Total Scores	**Low**	37%	84%	42%	32%	21%	37%	21%
	High	37%	0%	58%	58%	79%	63%	79%
	Unclear	26%	16%	0%	11%	0%	0%	0%

Figure 1. PRISMA flow diagram showing the literature search process and selection of studies.



Trial registration

PROSPERO: CRD42020183322

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Distal Tibiofibular Syndesmotic Widening in Progressive Collapsing Foot Deformity

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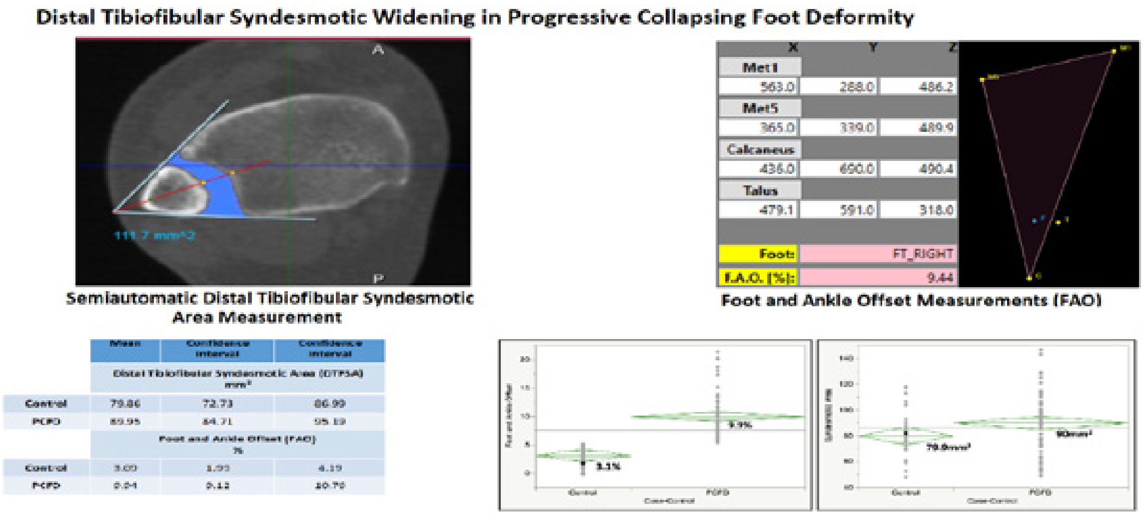
Introduction: Lateral overload in Progressive Collapsing Foot Deformity (PCFD) takes place as hindfoot valgus, peritalar subluxation (PTS) and valgus instability of the ankle increases. Fibular strain due to chronic lateral impingement may lead to distraction forces over the distal tibiofibular syndesmosis (DTFS). This study aimed to assess and correlate the severity of the Foot and Ankle Offset (FAO) as a marker of progressive PCFD with the amount of DTFS widening, and to compare it to controls [1,2,3].

Methods: In this case-control study, 62 symptomatic PCFD patients and 29 controls who underwent standing WBCT examination were included. Two fellowship-trained blinded orthopaedic foot and ankle surgeons performed FAO (%) and DTFS area measurements (mm2). DTFS was assessed semi-automatically on axial plane WBCT images, 1cm proximal to the apex of the tibial plafond. Values were compared between PCFD patients and controls, and Spearman's correlation between FAO and DTFS area measurements was assessed. P-values of less than 0.05 were considered significant.

Results: PCFD patients demonstrated significantly increased FAO and DTFS measurements in comparison to controls. A mean difference of 6.85% ($p<0.001$) in FAO and 10.4mm2 ($p=0.026$) in DTFS was observed. A significant but weak correlation was identified between the variables, with a Þ of 0.22 (p=.03) A partition predictive model demonstrated that DTFS area measurements were highest when FAO values were between 7 and 9.3%, with mean values of 92.7mm2 (SD 22.4) (Figure).

Conclusion: To the author's knowledge, this was the first study to assess syndesmotic widening in PCFD patients. We found PCFD patients to demonstrate increased DTFS area measurements when compared to controls, with a mean difference of approximately 10 mm2. A significantly weak positive correlation was found between FAO and DTFS area measurements, with the highest syndesmotic widening occurring when FAO values are in between 7 and 9.3%. Our study findings suggest that chronic lateral impingement in PCFD patients can result in a negative biomechanical impact on syndesmotic alignment, with increased DTFS stress and subsequent widening.



	Mean	Confidence interval	Confidence interval
	Distal Tibiofibular Syndesmotic Area (DTFSA) mm²		
Control	79.86	72.73	86.99
PCFD	89.95	84.71	95.19
	Foot and Ankle Offset (FAO) %		
Control	3.09	1.99	4.19
PCFD	9.94	9.12	10.76

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Do changes on the plantar system impact the binocular fusion?

Background: Multisensory integration is a fundamental brain mechanism allowing the integration of a multitude of inputs originating from the sense organs [1]. Interactions and convergences between individual sensory systems is modulated based on the integration of different sensory inputs like vision and proprioception [2, 3]. To assess the integration and participation of a system on multisensory integration, one could modify it sensory information and observe the reweighting on the others. Quercia and collaborators reported interaction into binocular fusion and audiovisual integration [4]. Mettey and collaborators reported interaction between stomatognatic system and binocular fusion [5]. The purpose of this study is to assess sensory reweighting of plantar system on the binocular fusion.

Method: To investigate the plantar system contribution on integration, we increasingly reduced the sensory foot sole afferent cue by 2 types of foams: Crispon Diabet® and Airgom®, Crispin France [6, 7]. The binocular disruption vision was assessed by the Verticale Heterophoria VH, measured by Maddox rod because ocular motor compensation is very weak in this plane [4, 5]. 40 subjects with VH were include and VH were scored on foam randomly.

Result: Only Crispon Diabet® induce reduction of VH (i.e increasing orthophoria, $p<0.005$; Figure 1 expose the number of VH depending the foam sensory condition).

Discussion: The foam reduced the plantar cutaneous participation in real time on multi integration [7]. The feedback, or lake of plantar information, induce new sensory situation. Then the somatosensory information is reweighted. We confirm that it is possible to modify visual perception by changing sensory plantar information. This influence is depending of the mechanical foam proprieties. Here, only one foam induce reduction of the VH. So we suggest that the plantar system could affect the visual integration and could influence binocular fusion. These findings support the hypothesis plantar sensory variation may be effective tools for evaluation of relationship between plantar and visual integration.

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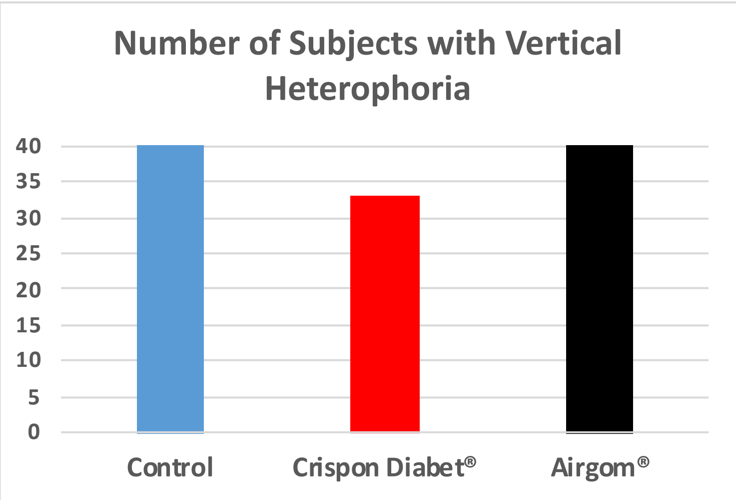

Clinical Registration SLMJ1/2019/APC 1605ES/2016-A01062--RCB-DM

Do Plantar Irritating Stimuli Types have the same repercussions on Balance Function disorders?

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Introduction: Plantar sole have an important participation in the balance function [1-3]. Epine Irritative Podale: nociceptive stimuli or plantar irritating stimuli (PIS), is one of feet pathologies, describes in 1945, witch exacerbating reflex mechanisms, increase or maintain an amplification of related influxes perpetuating or amplifying the nociceptive reflex [4-6]. PIS types 2 to 4 were not expressed by subjects. These are highlighted by CoP variations on foam: Moliser® to Lepork-Villeneuve (n°2, LV, [8]); Depron® to Foisy-Kapoula (n°3, FK, [9, 10]), Airgom® to Janin-Dupui (n°4, JD, [11, 12]). Those 3 foam present different thickness, schore, density and could influence clinical evaluation [13-15]. Also, FK did not recommend clinical tests in regard of their reproducibility's. Anyway, PIS influences could be objectives by clinical tests [8,11,12,16-18] like Standing Forward-Flexion Test's (SFT, validated as good, [18]). Currently, we don't know if those 3 PIS types (LV, FK, JD) induce the same Balance Function disorders. **Method**: To answer, we include 20 subjects of each PIS type according to the author's recommendation. SFT were randomly performed under 4 sensory conditions of support (Hard, Moliser®, Depron®, Airgom®). Physiological situations where the thumbs are aligned are counted (Table 1). **Results**: On hard, no differences were observed between SFT for LV, FK and JD, but physiological responses are exposed. Moliser® and Airgom® increase physiological responses to LV and more to JD but not to FK. In reverse, Depron® do not influence SFT for all PIS types. **Discussion**: Foam decrease the foot afferent cues and induce reduction of the nociception of PIS. Specific foam reduce exteroceptive/nociceptive dysfunction for LV and JD. Similar responses could expose that they will have maybe the same support [2, 3, 14, 15]. Also, absence of improvement induce by Depron® on PIS FK, LV and JD, could suggests that FK does not have the same support that LV and JD. We can propose either that FK PIS is not sensitive to plantar anaesthesia, in which case it is not PIS, or postural response on Depron® is specific. Indeed, technical characteristics of Depron® facilitate postural control due to its high density [16]. This could also explain the different results between the two specific foams for LV and JD. Airgom® is the least dense and therefore results could be comparable to the literature [2, 16]. Then 3 types PIS have not the same repercussion on Balance Disorders. In any case, the results expose false positives in all PISs.

	N =20	LV	FK	JD
Hard		4	5	3
Foam	Depron®	8	6	5
	Moliser®	11	5	13
	Airgom®	10	7	15

Table 1: Numbers subject's variations of physiological responses: thumbs aligned.

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Do we really need to worry about calcaneocuboid subluxation during lateral column lengthening for planovalgus foot deformity?

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Introduction: While lengthening of the lateral column through a calcaneal neck osteotomy is an integral component of flatfoot reconstruction in younger patients with flexible planovalgus deformities, the procedure has been implicated in iatrogenic calcaneocuboid (CC) subluxation and subsequent degenerative changes at the CC articulation. The purpose of this study is to characterize alterations at the CC joint following lateral column lengthening (LCL) as well as to determine if Steinman pin stabilization of the CC joint prior to distraction maintains a normal CC relationship.

Methods: Seven matched pairs of fresh frozen cadaveric feet underwent pre-procedure plain radiography and cross-sectional computed tomography (CT) imaging. LCL via a calcaneal neck osteotomy was then performed. One foot of each matched pair had a single smooth Steinman pin placed centrally across the CC joint prior to osteotomy distraction. Distraction across each osteotomy was then performed and maintained with a 12mm porous titanium wedge. Repeat imaging was obtained and compared to pre-procedure studies to quantify sagittal and rotational differences at the CC articulation.

Results: Following LCL, plain radiography demonstrated statistically significant increases in the percentage of the calcaneal articular surface dorsal to the superior aspect of the cuboid in both the pinned (8.2% vs 17.6%, p=0.02) and unpinned (12.5% vs 16.3%, p=0.04) specimens. No difference in the percentage of subluxation was found between the two groups following LCL. CT imaging demonstrated statistically significant increases in rotation between the calcaneus and cuboid following LCL in both the pinned (7.6° ± 5.6°, p=0.01) and unpinned (17° ± 12.3°, p=0.01) specimens. Though a greater degree of rotation was present in the unpinned specimens following LCL, this difference was not statistically significant (p=0.28).

Discussion: Both sagittal and rotatory subluxation seem to occur at the CC joint following LCL regardless of pin stabilization. As a single pin would be expected to limit pure translation while having little effect on rotation, it is possible that the rotational changes identified on three-dimensional imaging are interpreted as dorsal translation when viewed two dimensionally using plain radiography. Consideration should therefore be given to CC stabilization with two pins during LCL to prevent this rotatory subluxation.

Relevance: As rotatory subluxation of the CC joint during lateral column lengthening for flatfoot reconstruction occurs both with and without single pin stabilization, alternate means of stabilization, may be needed to prevent this.

Does the alteration in binocular fusion modify spontaneous walking? (Pilot Study)

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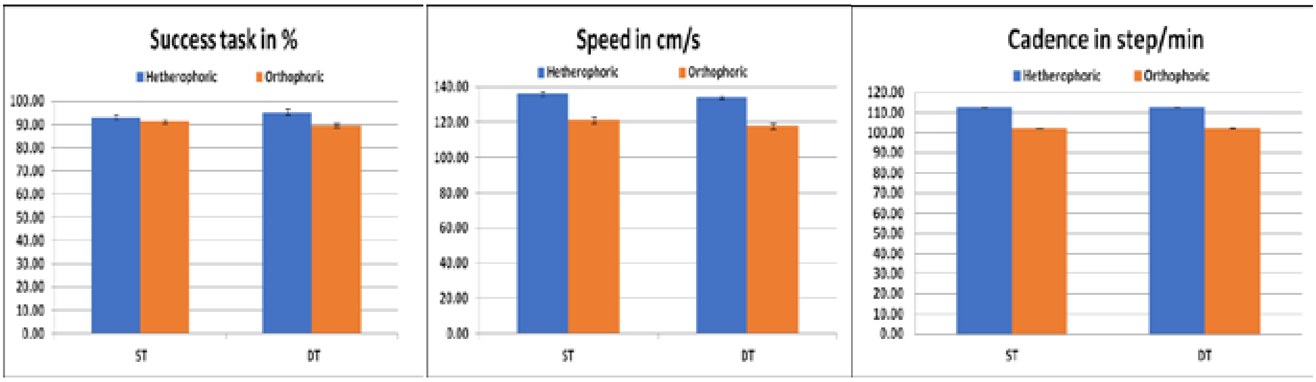
Introduction: Walking is a complex activity that involves both motor and cognitive control. Spontaneous walking speed is commonly used in clinical practice to stratify risk of functional decline and loos of autonomy in older people [1, 2]. A complementary approach consist in assessing the attentional cost of walking, using a dual task paradigm (i.e a cognitive task and motor task performed separately or simultaneously). When attention resources are limited, we generally observe a prioritization phenomenon: one of the tasks loses precision to the advantage of the other. Severals studies have shown that Maddox test inadequacy, witch refers to the alteration of binocular vision, alters the ability to concentrate and perform fine in learning disorders and DysproPrioception Syndrome [2]. Considering the role of cognitive functions in walking efficiency, and the effect of cognitive decline on this efficiency, it could be hypothesized that spontaneously walking speed is altered during a dual task in individuals suffering from alteration of binocular vision. **Methods**: 15 participants performed the Maddox test to detect alteration of binocular vision (7 males and 8 females aged 21±1 years). Scoring categorizes 2 groups according to ocular fusion status: with fusion or Orhtophoric group (O), without fusion or Heterophoric group with Maddox disorder (H). Spontaneously walking speed (speed, cadence) was evaluated, first, during single task (ST) and during dual task (DT) using a simultaneous assessment of working memory with the n-back test. **Results**: We found no cognitive difference during dual task, whatever the group. In contrast, spontaneously walking speed differed between groups, both during the single task and during the dual task. Group H had higher spontaneously walking speed than group O. This difference was mainly explained by a difference in walking cadence, ($p<0.05$). As can be observed in the figure 1, there was no interaction between conditions, since the difference between groups was similar in the single task and in dual task. **Conclusion:** Higher cadence in both tasks suggests that the binocular fusion have a negative impact on spontaneously walking speed that is independent of the cognitive status. Although there is no interaction (probably because of a lack of statistical power). The higher magnitude in DT than ST could illustrate the fact that the prioritization phenomenon between motor control and cognition in H subjects was closely linked to the loos of proprioception precision. This is in accord with Fettrow and collaborators: "cadence change related that neural control of balance is altered". This original study provides preliminary data that underscore the need to study more thoroughly the link between spontaneously walking condition speed and attention cost of walking in individual without binocular fusion.



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Does the Epine Irritative Plantaire Ns4, Plantar Irritating Stimuli, influence the Visual analog scale, Foot Function Index, Foot Posture Index, EFAS Scores?

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Introduction: Visual analog scale (VAS), Foot Function Index (FFI, [1, 2]), Foot Posture Index (FPI, [3, 4]), EFAS Score (EFASs, [5]) are a part of variety of clinical measurement tools used in podiatry to measure the impact of foot pathologies in terms of function, pain, disability and activity restriction [1]. One of those is Plantar Irritating Stimuli [6] (Epine Irritative Plantaire), plantar noxious stimuli type 4 (Ns4, [7, 8]) with asymmetrical perception of pain, loss of spatial discrimination and of somesthesia representations [8-10]. The purpose of this study, was to determine the impact of Ns4 on clinical scores of VAS, FFI, FPI, EFASs.

Methods: 2 groups 30 women and 30 men (29-54 years) with Ns4 (first metatarsal head) and without (C) were included. Scores of VAS on standing and pressure on 1 metatarsal head (VASM), FPI, FFI and EFASs (French validation, [5, 11]) were completed.

Results: No difference was observed for VAS on standing (2 / 3). Differences were observer into respectively C and Ns4 for VASM (2 / 8), FFI (14 / 83), FPI (+2 / +5), EFASs (27 / 17) ; (Figure 1).

Discussion: Ns4 scores are comparable of the influence of foot pathologies. VAS on standing C/Ns4 is not differentiating because Ns4 is under the express pain threshold [7-9]. FPI scores categorizes Ns4 like potentially pathological foot and FFI high score confirms its impact on foot function. This is reinforced by EFASs scores. Results expose, for the first time, that Ns4 impact Plantar System function in terms of posture, pain, disability and activity restriction.

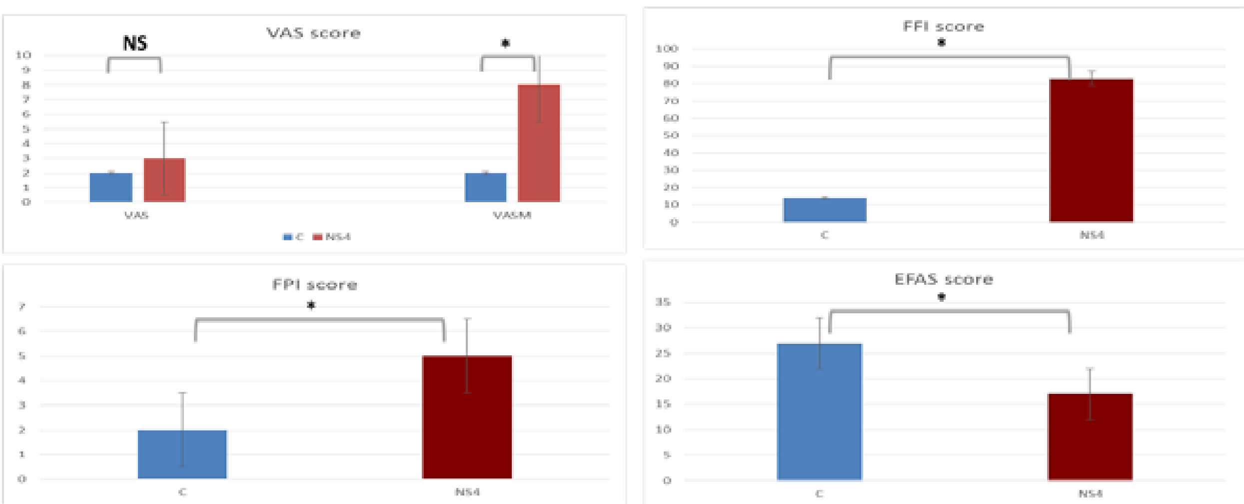

Figure 1: Scores of scales. VAS: Visual analog scale. FFI: Foot Function Index. FPI: Foot Posture Index. EFAS: European Foot and Ankle Society. *: significant effect. NS: no significant effect.
Clinical study registration APC 1605ES/2019MJ-A01062--RCB-DM

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Dynamic foot model before and after loading

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Introduction

3D image-based models of the foot can be extremely useful in the study of joint interaction even medical diagnosis. Experimental tests would require very invasive procedures which would most times only be possible in cadavers. Hence, this project involves the development of a dynamic foot model which can reproduce ankle kinematics. A validation study is also proposed in order to ensure the reliability of the results produced by the model. For this purpose, CT scans of that particular subject are taken during the stance position, where the foot has to withstand half of that person's bodyweight; and also while sitting down, where the foot is assumed to not be experiencing any sort of loading. The displacement of the bones during these two conditions is compared with the displacement described by the dynamic model as the same loading is applied.

Results

The dynamic ankle model consists of a foot on a fixed flat surface, where the bones forming the ankle joint are included, as well as the midfoot bones up to the metatarsals. During the simulations, all the bones are free to move in any direction; apart from the tibia, which is constrained to stay perpendicular to the surface. The interaction between the bones' surfaces is assumed to be frictionless, but no penetration is allowed. Still, some friction is defined for the contact between the foot and the surface. Lastly, the ligaments, modeled as tension-only element forces with non-linear strain properties, keep the bones together. The results are recorded when an axial load of half bodyweight is applied downwards on the tibia (Figure 1).
For the validation study, the CT images obtained from one subject while standing and sitting down (loaded foot and unloaded foot) are rendered as 3D objects in order to observe the displacement that the bones go through. The bones seem to mainly undergo an external rotation of a few degrees when the foot is loaded (Figure 2).

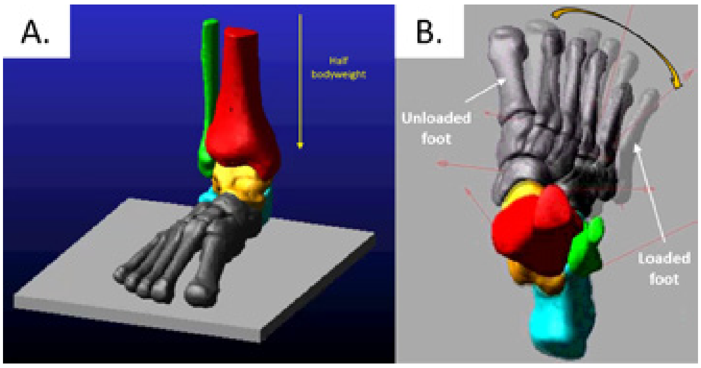

Figure 1. Dynamic foot model. (A) Static unloaded foot showing the direction of the applied load. (B) Unloaded foot at the start of the simulation vs loaded foot (faded) after running the simulation

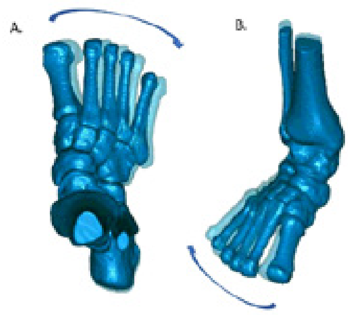

Figure 2. 3D bones showing unloaded foot vs unloaded foot (faded) from CT scans. (A) Top view (B) Isometric view

Conclusions

A dynamic ankle model can serve as a very powerful tool for the analysis of the biomechanics of the foot. To achieve this, a good validation method is required to ensure the results from the model are as accurate as possible. The opportunity of studying the bones' behavior from the same subject can provide very significant information. Thus, matching the displacement of these bones during a dynamic simulation would greatly improve the reliability of the model.

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Effect of a high-intensity interval training in the ankle kinematics during a treadmill protocol in amateur runners

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Funding: São Paulo Research Foundation – FAPESP, Brazil [grant #10/20538-7 and #18/20362-8].

Introduction: The high-intensity interval training (HIIT) has been used for physical performance improvement. However, it is still not clear if HIIT may lead to lower limb injuries due to the high intensity of this type of training [1]. Therefore, this study aimed to verify the effect of the HIIT protocol during treadmill running in ankle kinematics.

Methods: Eighteen male amateur runners (24,16 ± 3,47 years; 79,53 ± 6,98 kg and 1,79 ± 0,63 m) performed a HIIT protocol on a treadmill (Inbrasport Millennium ATL) that was divided into sprints with 30s of duration followed by 15s passive resting until the inability of the participant to continue performing the protocol. The speed used during the protocol was defined at 120% of the maximum speed running [2] obtained in an incremental protocol previously performed. The first and last sprints were analyzed and the three-dimensional motion data were collected by a motion analysis system with thirteen infrared cameras (OptiTrack™, USA) operating at 250 Hz that tracked 26 lower-limb reflective markers. The *shanks* and *feet* segments were defined in order to calculate the Euler angles, defined as: *x-axis* [plantar flexion(+) and dorsiflexion(-)]; *y-axis*[adduction(+) and abduction(-)]; *z-axis*[external(+) and internal(-) rotation] and posteriorly the angles curves waves were time-normalize(0-100%). Ankle kinematics in the three planes of the first and last sprint trials were compared using the Student's t-test for paired samples calculated with Statistical Parametric Mapping (SPM) with p<.05 [3].

Results: The participants showed higher dorsiflexion in the first sprint compared with the last one. The SPM plots showed differences between 22-26% of the running cycle for the right ankle (p=0.05; t*=3.07) and between 0-4% (p=0.044) and 10-25% (p=0.005) of the running cycle for the left ankle (t*=3.07). In addition, during the end of the swing phase, on the preparation to the next step, greater dorsiflexion was also found in the first sprint, but observed during 94-100% and 90-100% of the running cycle for both, right and left ankles, respectively (Figure 1). No differences were found in the frontal and transversal planes.

Discussion and conclusion: The runners presented a decreased dorsiflexion in the last sprint compared with the first, likely justified by the muscle fatigue caused by the HIIT protocol.

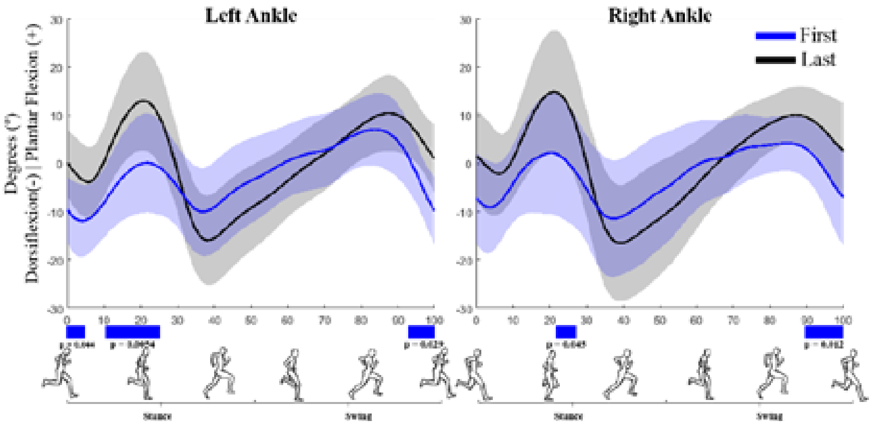

Figure 1. Ankle sagittal angles (Dorsiflexion [-] / Plantar Flexion [+]), during the running stance phase measured in during the first (blue) and last (black) sprints of a high-intensity interval training performed on a treadmill. The bars at the bottom of the figure represent the cycle phase where the significates differences between the first and last sprint.

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Effect of plantar flexor muscle strengthening on the gait of children with idiopathic toe walking: preliminary results

Introduction: Idiopathic toe walking (ITW) is a condition in which children walk on tip toes with no neurological, orthopedic or psychiatric causes. The gait of children with ITW is characterized by early activation of the plantar flexors (PF) and superposition of its activity on the dorsiflexors (DF). The morphology of the PF is characterized by predominance of type I fibers and possible weakness. There are few studies on the rehabilitation of these children, and a recent systematic review shows that the studies in the literature are of low methodological quality and small sample size.

Purpose: To evaluate the effect of plantar flexor strengthening associated with conventional physiotherapy treatment in children with ITW.

Methods: Fourteen children of both sexes diagnosed with ITW, aged 5 to 11 years, were recruited and randomized into two groups, namely: the control group (CG), which underwent gait training, TS muscle stretching, anterior tibialis (TA) muscle strengthening, motor sensory training and intervention group (IG), who were submitted to the same training as the CG and additionally muscle strengthening of the TS. The intervention was performed twice a week for eight weeks. The children underwent a two-dimensional kinematic analysis of gait, passive range of dorsiflexion movement, isometric dynamometry of the AT and ST muscles, motor coordination, quality of life and parental perception of equine gait at baseline and at the end of treatment.

Results: Both groups showed a statistically significant increase in dorsiflexion, muscle strength of TS, quality of life and shorter time in equine gait reported by the parents' perception when comparing pre and post treatment intra groups. No statistically significant differences were found between the groups in the studied variables. However, active dorsiflexion and muscle strength of sural triceps were clinically more significant in the intervention group, (there was a final mean difference of 3.4 between groups, with an effect size of 0.84 on active dorsiflexion, and a mean difference 15.5 in muscle strength strength, with effect size of 0.79).

Conclusion: Strengthening of the plantar flexor muscles in children with idiopathic equine foot increases active dorsiflexion, muscle strength, quality of life and shorter time in the horse by parental perception.

Relevance: The findings of the present study can expand treatment alternatives for children with ITW.
Key words: Idiopathic toe walking, children, strengthening, plantar flexor muscles

Effectiveness of children's therapeutic stability footwear: A Delphi consensus on outcome measures

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Introduction

Mobility impairment affects approximately 2% of the global childhood population; therapeutic stability footwear is an assistive aid that is designed to influence movement of the foot and ankle and is commonly used for these children [1,2]. However, there appears to be no agreed consensus on what conditions this footwear should be prescribed for and what are the salient outcomes to determine their clinical effectiveness [2]. Identification and consensus agreement of outcomes in both clinical research and practice allows for a unified measure of the effectiveness of an intervention, informing on value-driven health care and the development of a consistent evidence base.

Methods

Eighteen experts who have experience in providing clinical footwear to children with mobility impairment took part in a Delphi survey to reach consensus. The first round consisted of soliciting expert opinion on seven medical conditions, identified from the collective research [2], and salient outcome measures for therapeutic stability footwear intervention. These opinions were analysed grouped and fed back to the panel in ranked level agreement statements. Over two further rounds, statements were reviewed and modified, or new statements were developed based on panellist feedback. Consensus on a statement was reached at relative frequency agreement ≥75%.

Results

Five out of the seven medical conditions proposed reached a consensus amongst the panel (Table 1). Forty-nine statements proposed by the panel concerning outcomes were collapsed and grouped into eight outcomes for all five conditions, Eight of these reached consensus as salient outcomes: six specific spatiotemporal variables were identified and, kinematic measures included available range of ankle motion and optimising lower limb movements to a condition-specific tool (Edinburgh Gait Scale, Hoffer Ambulation score) or normative data sets. Although kinetic outcomes of heel and forefoot loading were proposed by the panel, these did not reach consensus.

Table 1 Expert panel consensus of conditions and outcomes for stability footwear intervention in childhood mobility impairment

Medical condition	**Outcomes**	
	Spatiotemporal	Kinematic
Cerebral Palsy Spina Bifida Symptomatic Pes Planus Duchenne Muscular Dystrophy Down's Syndrome	**Stride length** **Cadence** **Velocity** **Timed Up and Go** **10 Meter Walk Test** **6-minute walk test**	**Optimising lower limb movement** against condition-specific tools (Edinburgh Gait Scale†, Hoffer Ambulation Score‡,) or normative data sets [3]protocols are required to process data and produce a few meaningful summary measurements which can, in turn, be used to flag gait abnormalities. Earlier work produced a one-dimensional index of gait, calculated from sagittal hip, knee and ankle rotation angle patterns. The objective of this study was to extend the original index, incorporating kinematic and kinetic data from multiple planes, while allowing for correlations between component measures. A one-dimensional index of normal gait was developed, based on normative gait data (N = 45 children, aged 3-13 years **Ankle Range of Motion** (Passive and Weightbearing)
†Cerebral Palsy only, ‡ Spina Bifida only		

Discussion

The Delphi survey has identified and achieved expert panel consensus on medical conditions that may benefit from stability therapeutic footwear intervention and the salient range of outcomes to assess their clinical effectiveness. This will allow for the development of a consistent range of measures to assess the impact of this intervention on children's gait in both research and clinical practice and healthcare strategies to improve the mobility of these children.

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Effects of a foot-ankle exercise program on foot muscle strength and functionality in people with diabetic neuropathy: a preliminary data release from an ongoing randomized clinical trial

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Background: There are several progressive foot-ankle musculoskeletal alterations in people with diabetic neuropathy (DPN), mainly related to losses in the foot-ankle function (strength and flexibility) that lead to gait complications and affects the quality of life [1]. Due to this context, protocols for preventing those musculoskeletal and functional changes are encouraged and the new Guidelines of the International Working Work of the Diabetic Foot recommends foot-related exercises focusing on strengthening and flexibility. The purpose of this study was to evaluate the effects of a foot-ankle therapeutic exercise program on foot muscle strength and foot-ankle functionality in people with DPN, as a preliminary data release from an ongoing randomized controlled single-blind trial. Current Controlled Trials NCT02790931

Methods: 38 patients with DPN (23 F, 15 M, 64.0 ± 9.4 yrs old) were randomly allocated to a control group (CG, n = 18) with usual care or an intervention group (GI, n = 20) with supervised foot-ankle exercises by a physiotherapist for 12 weeks. Patients were evaluated for biomechanical (foot muscle strength), clinical and functional measurements (gait speed, tactile sensitivity, passive ankle range of motion, quality of life, health and functionality of the foot) at baseline (T00), after 6 weeks (T6) and after 12 weeks (T12) of treatment. ANOVAs 2-way to investigate interaction effects between groups and assessments were performed ($p<0.05$).

Results: There was a difference between CG x IG after 12 weeks of foot-ankle exercise program, with significant improvement on fast gait speed in the intervention group [CG=1.48(0.37); IG=1.68(0.38); p=0.049]. No significant differences were founds between groups for others assessed variables after 6 and 12 weeks of treatment (Figure 1).

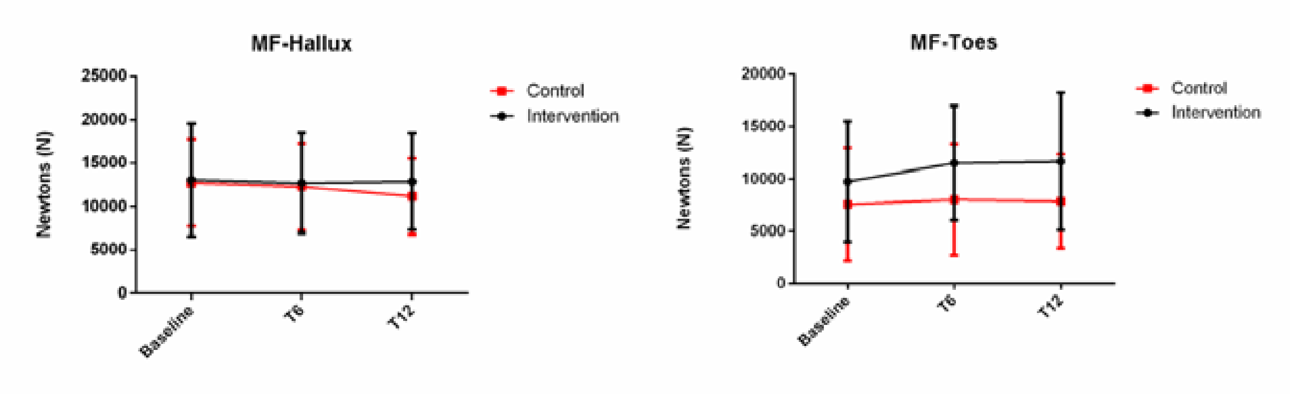

Figure 1: Maximum Force (MF) of the Hallux and Toes between groups in baseline, T6 and T12.

Conclusion: In this preliminary study from an ongoing RCT, it was possible to detect an improvement in the fast gait speed after 12 weeks of foot-ankle exercise program in diabetic patients with DPN. At this moment, it is not possible to confirm if the intervention planned has the potential to change other outcomes.

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Effects of a foot-ankle exercises on plantar pressure and foot-ankle functionality in people with diabetic neuropathy: preliminary data release from a randomized trial

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Background: Recent guidelines for treating and preventing diabetic foot complications are based on the management/control of diabetes, integrated foot-care, patient education, and self-management of foot-care [1]. Considering other rehabilitation approaches, specific foot-ankle therapeutic exercises have also shown promising results for improving sensitivity, foot-ankle range of motion and Diabetic neuropathy (DPN) symptoms [2], as well as for redistributing plantar pressure during locomotion [3]. However, those exercises are still not as common as footwear interventions in DPN people, and still require adequate investigation in well-designed studies prior to complementary recommendation in integrated care. The purpose of this study was to evaluate the effects of a foot-ankle exercise program on plantar pressure distribution during gait in people with DPN, as a preliminary data release from an ongoing randomized controlled single-blind trial. Current Controlled Trials NCT02790931.

Methods: A total of 32 patients with DPN (20 F, 12 M, 64.0±9.4 yrs old) were randomly allocated in a control group (CG, n=14) with usual care or a intervention group (IG, n=18) with supervised foot-ankle exercises by a physiotherapist for 12-weeks. The patients were evaluated for plantar pressure distribution during gait at self-selected speed in 10 plantar areas (forefoot, midfoot and heel) (Fig. 1), at baseline (T00) and after 12-weeks (T12) of treatment. The load parameters evaluated were: maximum mean force (N); peak pressure (kPa) and plantar-time integral (kPa*s). ANOVAs 2-way were used to investigate interaction effects between groups and assessments times ($p<0.05$).

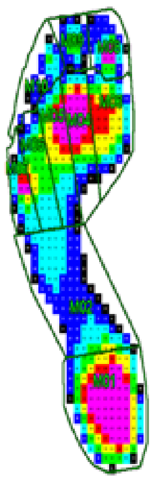

Fig 1. Footprint of 10 region of interest

Results/Conclusion: In this preliminary study from an ongoing RCT, it was not possible to detect differences between groups and effects of the foot-ankle intervention on plantar pressure variables in DPN patients. At this moment, it is not possible to confirm if the intervention planned has the potential to change those outcomes.

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Effects of a foot-ankle exercises protocol on lower extremity kinetics and kinematics during running: results of a randomized controlled trial

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Background: The human foot is a complex structure and provides an essential role during the running activity: absorbing, storing, transferring and returning energy. Despite the number of interventions that have been proposed to reduce the running-related injuries (RRI), their incidence is still high (up to 79%). Therefore, the purpose of this study was to evaluate the effects of a foot-ankle exercises protocol on lower extremity kinetics and kinematics during running in recreational long-distance runners.
Methods: A total of 54 injury-free runners (40.4±7.0 yrs old) were randomly allocated to either a control (CG = 31) or an intervention (IG = 23) group. Foot-ankle kinematics (multi-segment Rizzoli Foot Model [2]) and ground reaction forces were collected while running on an instrumented treadmill (AMTI) at a self-selected speed. The runners were evaluated at baseline (T0), and after 8 weeks (T8). The IG performed a foot-ankle strengthening exercises program once a week with a physiotherapist and were remotely assisted more 3 times/week. Temporal series variables of the leg, calcaneus, midfoot, forefoot and hallux were evaluated. Impact peak, vertical average load rate (VALR), impulse and ankle power were also calculated. The range of motion (ROM), minimum (MIN) and maximum (MAX) values were extracted. Interaction effect for each variable was statistically analyzed using a two-way, repeated measures ANOVA $p<0.05$) with Bonferroni post hoc test.
Results: There were no differences between CG and IG at baseline. When compared to the CG, the IG increased in 23% ($p=0.020$) the ROM between calcaneus and metatarsus (Cal-Met) in the frontal plane (eversion/inversion) in T8. Also, the ROM between calcaneus and midfoot in the transverse plane was (abduction/adduction) 21% ($p=0.021$) greater in the IG compared to the CG in T8 (Figure 1). There were no statistically significant differences for impact peak, VALR, impulse and ankle power.
Conclusion: These results suggest that 8-weeks of foot-ankle exercises program modified the foot biomechanics in recreational runners. Larger ROM in the IG shows that the foot is capable to improve its biomechanics as a response to the exercise protocol. Interventions focusing on the foot-ankle muscles should be considered to reduce RRI.

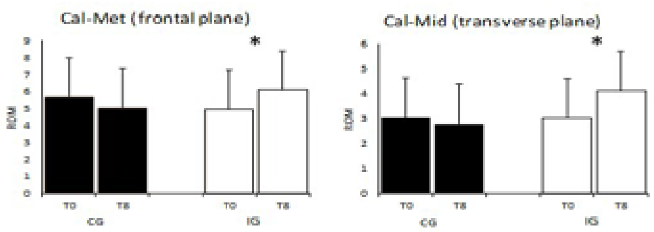

Figure 1. Range of motion (degree) between the calcaneus and metatarsus in the frontal plane and between the calcaneus and midfoot in the transverse plane throughout the stance phase of running. * indicates significant statistically sugnificant difference.

Acknowledgements: FAPESP – Matias 2016/17077-4 and Caravaggi (FAPESP #2017/23975-8) scholarships. FAPESP funded the Project 15/14810-0.

Trial registration
Clinicaltrials.gov Identifier NCT02306148

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Effects of a foot-ankle strengthening program in the clinical and functional aspects of people with knee osteoarthritis: a single-arm pilot study

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Background: Hip and knee muscles strengthening is strongly recommended for pain reduction and functionality improvement in knee osteoarthritis (KOA) patients[1]up-to-date, patient-focused, evidence-based, expert consensus guidelines for the management of knee osteoarthritis (OA. However, due to increased pain while performing some exercises, there is usually a reduction in patients' adherence to these protocols [1]. On the other hand, the use of flexible minimal footwear can lead to significant pain reduction and improved function in KOA women [2]. This result suggests that increased neuromuscular function of foot intrinsic muscles may help dampen impacts and reduce knee pain [2]. This study aimed to evaluate the effects of a foot-ankle muscles strengthening program on knee pain and functionality of KOA individuals.

Methods: Throughout a single-arm pilot study, 28 individuals diagnosed with KOA were contacted for scheduling and 7 were recruited based on the clinical and radiographic criteria of the American College of Rheumatology. Patients included were between 40 and 75 years, with grade II or III KOA, body mass index< 35kg/cm^2 and worst pain in the last week between 30 and 80 mm in the Visual Analogue Scale (VAS). They were performed a 6-week foot-ankle strengthening program. The self-related pain, knee stiffness and function were assessed by the WOMAC Questionnaire and foot strength was measured using a pressure platform (EMED, Novel, Munich, Germany) [3]. All procedures were performed before and after the intervention and paired t-tests were used to compare assessments ($p<0.05$). Pearson coefficients were used to identify relationships between knee pain and foot strength.

Results: Four subjects finished the treatment (3 men; 1 woman; Exclusions: (1) knee pain, (1) plantar fasciitis crisis and (1) could not participate). Knee pain level decreased significantly with large effect size (p=0.015; CI95%=1.86-11.63; *d*=2.39). Greater strength and function self-related were observed, but without statistical difference. In addition, negative correlation was observed between decreased of knee pain and increased of strength foot muscles in the affected limb, but without statistical difference (*r*=-0.650, p=0.350, for hallux; *r*=-0.596, p=0.404, for toes).

Conclusion: Foot-ankle strengthening program seems to reduced knee pain in people with KOA.

Trial registration: NCT04154059

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Effects of foot-core strengthening on the lower extremity distal power output during running: results of a randomized controlled trial

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Background: Previous findings have linked alterations in foot-ankle complex with running-related injuries (RRI)(1). During running, foot muscles function are important given the higher loads involved in these activities compared to walking. One problem identified is the fact that the methods used to estimate the lower extremity distal power typically models the foot as a rigid segment and thus prevent to quantify the mechanical power absorbed and generated by this segment. We aimed to test the effect of a 8-weeks foot-ankle exercise intervention in runners on the distal power output, modeling the foot as a deformable segment (2)AJ.
Methods: A total of 34 injury-free runners were randomly allocated to a control (CG=15) or an intervention (IG=19) group. Foot-ankle kinematics at 100Hz (multi-segment Rizzoli Foot Model (3)) and ground reaction forces at 1kHz were collected while running on an instrumented treadmill (AMTI) at a self-selected speed. The runners were evaluated at baseline (T0), and after 8 weeks (T8). The IG performed a foot-ankle strengthening exercises program once a week with a physiotherapist and were remotely assisted more 3 times/week. The ankle mechanical power was calculated from the forces and torques acting at the foot segment, by inverse dynamics approach using a 6-degrees of freedom ankle model. To assess the contribution of the foot segment as a deformable element, the foot power was calculated according to (2). The ankle joint power (Par) is the sum of the ankle power (Pank) and the foot power (Pft). We calculated the ratio of max ankle power (Pank) and min foot power (Pftd) between sessions (SII-T8/SI-baseline) within each group, to compensate for the different inter-subject running speeds. Independent t-tests were performed to compare the ratios between groups ($p<0.05$). Clinicaltrials.gov Identifier NCT02306148
Results: The statistical results revealed no difference between groups indicating no effect of intervention on the dependent variables (Figure 1).
Conclusion: The present results suggest that the foot exercises program might not be effective to change the ankle and foot power. The model used to estimate the foot power, although considers the foot as a deformable element, does not address the forces and moments at the multiple foot segments. Thus, as the intrinsic foot muscles crosses multiple joints, it is possible that any changes in foot powers due to the intervention would not be perceived by this model.

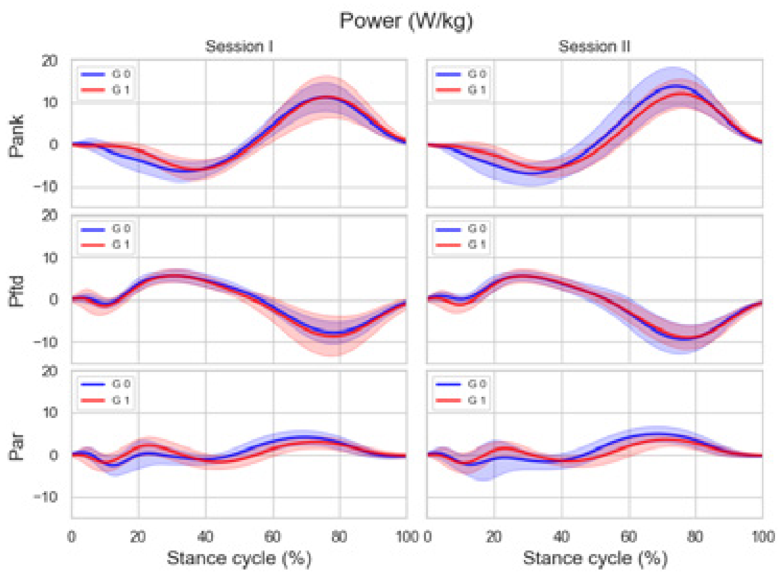

Figure 1. Ensemble average (±1 SD) time series of the ankle power (Par), foot power (Pftd) and total power (Par) of IG (gruop 1) and CG (group 0) Session I – Baseline, Session II, after 8 weeks of the intervention.
Acknowledgements: FAPESP – Matias 2016/17077-4. FAPESP funded the Project 15/14810-0.
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Effects of Intrinsic Foot Muscle Strengthening on the Medial Longitudinal Arch Mobility and Function. A Systematic Review.

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Introduction: The foot is composed by active, pasive and neural components [1]. The medial longitudinal arch (MLA) is held by the interaction of those structures, and the intrinsic foot muscles (IFM) have an important role [1,2]. In the last years many studies emerged about this group of muscles, bringing a variety of protocols for their strengthening. However, there is no standard protocols regarding its strengthening.
Objective: To analyze the effects of the intrinsic foot muscles strengthening and training volume on the medial longitudinal arch mobility to define the best training model.
Methods: The search was carried out on the following database: *Cochrane Central, Pubmed, PEDro, LILACS, Scielo, Embase, Cinahl e Science Direct*. Eligibility criteria was randomized clinical trials with IFM strengthening protocols, comparing with a control group (no intervention) or groups underwent another kind of intervention (i.e. foot insoles). Outcomes were MLA height and functionality. The Cochrane risk of bias table and PEDro (*Physiotherapy Evidence Database*) scales were applied to determine the methodological quality of the included studies. To assess the quality evidence level, the GRADE (*Grading of Recommendations, Assessment, Development and Evaluations*) approach was used.
Results: A total of 4 studies were included. The IFM strengthening did not promote better MLA support in short term, but there was significant better sustain in medium term (table 1). The quality of evidence was considered low. It was observed improvement for functionality on short and medium term, although the quality of evidence was classified as very low (table 1). The most used exercises were the *Short Foot Exercise* (SFE) and the *Toe Towel Curl Exercise* (TTCE), with 5 seconds contraction each repetition and progression from sitting position to standing position.
Relevance: The intrinsic foot muscles perform an important role on MLA dynamic stabilization. The lack of consensus makes difficult to apply the best protocols and therefore may influence the results. This study may help researchers and clinicians deciding and develop better protocols.
Conclusion: The intrinsic foot muscle exercises can influence in the MLA changes, in medium term (8 weeks), and increase dynamic balance outcomes in short (4 weeks) and medium term.

Table 1: Summary of evidence GRADE comparing

Short Foot Exercise compared with Toe Towel Curl Exercise for Medial Longitudinal Arch						
Patient or population: Healthy individuals **Intervention: Short Foot Exercise** **Comparison: Toe Towel Curl Exercise**						
Outcomes	**Illustrative comparative risks (95% CI)**		**Relative Effect (95% CI)**	**No of Participants (studies)**	**Quality of the evidence (GRADE)**	**Comments**
	Assumed risk	**Corresponding risk**				
	TTCE	**SFE**				
Navicular Drop (Short Term)[1]	The mean Navicular Drop ranged across control groups from 31.1mm to 47.8mm	The mean Navicular Drop in the intervention groups was 3,25 mm higher (0.14mm lower to 6.64mm) higher)	Mean Difference 3.25 (-0,14 to 6.64)	32 feet (one study)[2]	α **low**	No statistical difference between groups
Navicular Drop (Medium Term)[1]	The mean Navicular Drop ranged across control group from 9.54mm to 15.52 mm	The mean Navicular Drop in the intervention groups was 1.40 mm lower (0.86mm to 1.76 mm lower)	Mean Difference 1.40 (0.86 to 1.76)	30 subjects (one study)	α **very low**	-
Functionality: y-test (Short Term)[1]	The mean Y-test value ranged across control groups from 43mm to 49.3mm	The mean y-Test in the intervention groups was 0.05 mm higher (3.53 mm lower to 3.46 mm higher	Mean Difference 0.05 (-3.53 to 3.46)	32 feet (one study)[2]	α **low**	
Functionality: CAIT questionnaire (medium term)[1]	The mean CAIT score ranged across control groups from 20.66 to 24 points	The mean CAIT score in the intervention groups was 3.47 points higher (2.23 to 4.71 points higher)	Mean Difference 3.47 (2.23 to 4.71)	30 participants (one study)	α **very low**	

[1]short-term from 1 to 4 weeks, medium-term 5 to 8 weeks, and long-term 9 to 12 weeks.
[2] the study used both feet of each participant.

Resistration: *International Prospective Register of Systematic Reviews* (PROSPERO) - CDR 42018066422; and CEP UNIFESP 3204210219.

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Effects of three types of foot orthoses on the knee joint of posterior tibialis tendon dysfunction population

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Introduction:
Posterior tibialis muscle is the main invertor of the ankle joint. Posterior tibialis tendon dysfunction (PTTD) is characterized by a loss of function of the posterior tibialis muscle secondary to a tendon deterioration (tendinosis). Also, the inversion ankle joint moment of PTTD individuals is increased compared to healthy population [1]. Foot orthoses (FOs) can reduce the inversion ankle joint moment in PTTD population [2]. But little is known about the collateral effects of the foot orthoses in PTTD population on the knee joint. The aim of this study was to investigate the effects of three different types of FOs on the knee joint moment in PTTD population.
Methods:
Fourteen (14) individuals were recruited. Inclusion criteria were based on the guidelines of Johnson and Strom's classification [3] for stage 1 and 2 PTTD. A three-dimensional (3D) motion analysis system (10 cameras, Vicon, Peak, UK) was used to track the lower limb motion during gait at a sampling rate of 100Hz. The modified Oxford foot model Wright, Arnold [4] was used to make the model of each individual. Four force plates (Model BP400600NC, AMTI Inc., Watertown, MA, USA) simultaneously recorded the ground reaction forces at a sampling rate of 1000 Hz. Five walking trials were performed for each test condition. It was used in each condition with a shoed condition (Shoe), a prefabricated FOs condition (Prefab), a neutral custom FOs condition (Custom) and a five degrees varus (medial wedge) with a 4 mm medial heel skive custom FOs condition (Custom - Varus). To compare the effect of the four different conditions, a curve analysis was performed using 1D statistical parametric mapping (SMP) (Matlab, Mathworks inc.) for each dependent variable [5, 6].
Results:
Custom and custom-varus conditions increased the knee joint abduction moment at different times during the support phase of gait compared to shoe and prefab conditions (Fig. 1).

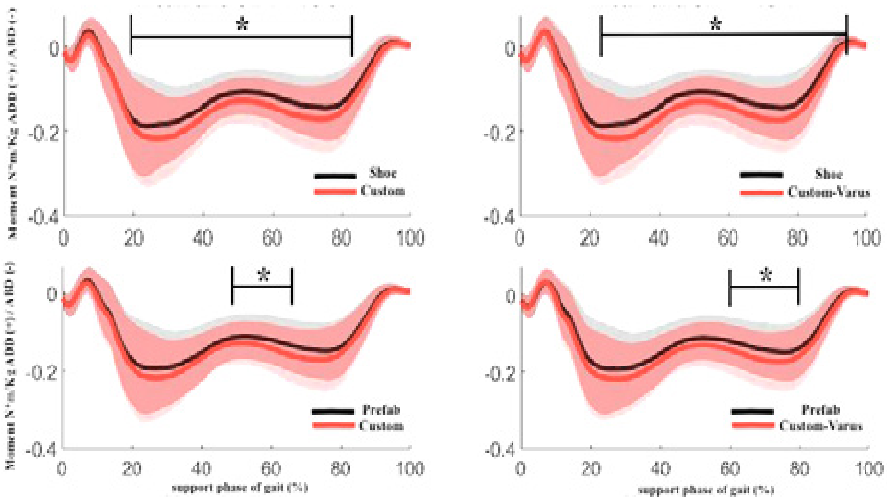

Figure 1 **: Knee joint moment in the frontal plane during the support phase of gait. * p < .001**

Discussion:
When assessing knee joint moments with custom or custom-varus conditions compared to shoe or prefab conditions, a significant increase of the knee joint abduction moment was observed. A greater knee abduction moment can potentially cause other issues at the knee joint like knee osteoarthritis [7].On the other hand, Maeda, H. et al. has shown that PTTD population has a tendency to have lower knee abduction moment compared to healthy population [8]. Results of this study show a tendency that custom foot orthoses can bring closer the knee joint moment of PTTD population to what is seen in healthy population. Further research should focus on the clinical meaningfulness of those biomechanical results to see if FOs are detrimental or beneficial for knee joints of PTTD individuals.
Clinical relevance:
The present results of this study will help to better understand the FOs effects on the knee joint function in PTTD individuals.

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EMG alteration in diabetes subjects with and without neuropathy varies across different tasks: comparison among EMG activity in overground, treadmill walking and stair negotiation

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Introduction

Peripheral neuropathy (DPN) is one of the most severe complications of diabetes [1]; one of the most widespread chronic diseases [1]. Several studies analyzed surface electromyography (sEMG) signal in diabetic subjects (DS) with and without DPN, but there isn't an agreements in terms of which are the most impaired muscles [2-4]. In the literature, the studies varied in term of either type of task or sEMG parameters analyzed [3-5]. The aim of this work was to verify the impact of different activities and type of sEMG analysis on the detection of lower limb muscle impairments in diabetic subjects with (DNS) and without DPN. For this purpose, 3 activities were compared: stair negotiation (SN), overground (OW) - treadmill walking (TW).

Methods

Sixty subjects took part in the study, after signing informed consent: 20 controls ((CS) age: 59.8±6.3years, BMI: 26.1±7.7 kg/m²); 20 DS age: 61.6±9.0 years, BMI: 26.3±2.4 kg/m²); 20 DNS age: 62.0±7.8 years, BMI: 27.4±5.8 kg/m²). Two sEMG systems (BTS POCKETEMG, 1000Hz–OW/SN and FreeEmg, 1000Hz–TW), stereophotogrammetry (6 cameras, 60Hz BTS), 2 webcam (Logitech 30Hz), 2 force plates (Bertec FP4060, 960Hz), plantar pressure insoles (Novel Pedar, 100Hz) were used. During OW and SN, 6 muscles were recorded bilaterally - Rectus Femoris (RF), Tibialis Anterior (TA), Peroneus Longus (PL) Gastrocnemius Lateralis (GAL), Gluteus Medius (GM), Extensor Digitorum Communis (EXD); during TW, 4 muscles were acquired (RF, TA, GAL, EXD). sEMG activity duration, onset-offset, envelope peaks were determined [3,5].

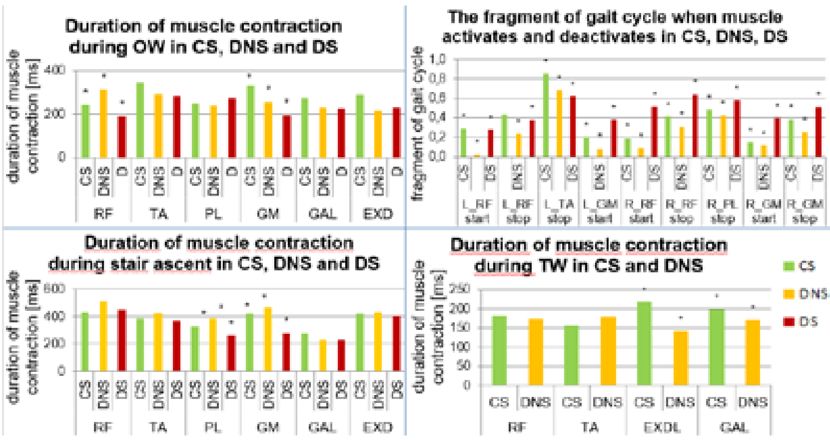

Figure 1. Duration of muscle contraction, onset and offset activation during gait; duration of muscle contraction stair ascent (in CS, DNS and DS) and treadmill exercise (CS, DNS) (*-significant difference)

Results

During OW differences in duration of RF, TA and GM were detected in both DNS and DS, while prolonged duration of left PL activity was observed only in DS. During TW a shorter duration of both EXD and GAL's activity was observed. SN revealed differences in duration of PL and GM contraction (Figure 1).

Discussion

The key finding of this study is that the alterations detected in lower limb muscles activity on both DS and DNS with respect to CS varied across the different tasks. This should be taken into account when adopting sEMG as a screening for detecting muscle impairments in these subjects.

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Excessive stiffness interrupts alleviation of stress on the heel pad: Finite element analysis

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Heel pad has a significant role during the gait because it can absorb the energy shock and relieve the stress. However, it is difficult to measure the variation of the heel pad stiffness during the gait because the stiffness and the distributed force on the heel pad change continuously. Therefore, in this study, as the distributed force on the heel pad is increasing, the variation of stiffness is observed with two different body weight.

For the computational modeling, ABAQUS/CAE 2017 was used. The model consisted of three parts: indenter, foot plate, and heel pad. The element type of the indenter was C3D4, and the element type of the plate and the heel pad was C3D6. Indenter and foot plate were set as the steel for material properties. The heel pad was modeled as the Ogden form, the hyper-elastic material [1]. To input the uniaxial test data for the Ogden form, two subjects (Female, 47kg, 55kg) were chosen for the heel-pad indentation experiment. In step 1, to press the heel pad, the plate moved along the z-axis. Eight cases were set up for the displacement of the plate from 1mm to 8mm with 1mm interval. In step 2 as the implicit dynamic, to measure the heel pad stiffness, the indenter moved up to 10mm for two seconds along the z-axis. To represent the increasing pressure on the heel pad, the compressibility index was used [2].

The stiffness of the heel pad was 2.535 ± 0.361 kPa when the heel pad was not compressed. The stiffness of the heel pad was 10.194 ± 0.449 kPa when the compressibility index was maximum (Figure 2).

Heel pad becomes rapidly stiffer to maintain its shape in normal condition, but it provides limited amount of protection. When abnormal load is distributed, the stiffness becomes gradual. Heel pad can dissipate abnormal energy for preventing heel pad fracture, but local defects and changed material property cause more local stress and finally heel pain.

Figure 1. Heel pad, foot plate, and indenter finite element model

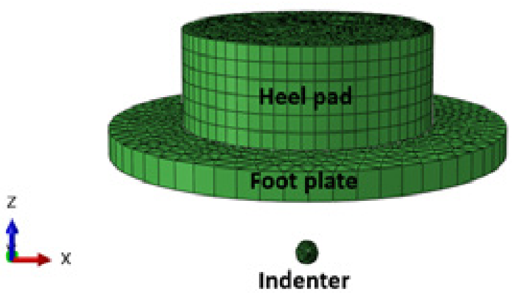
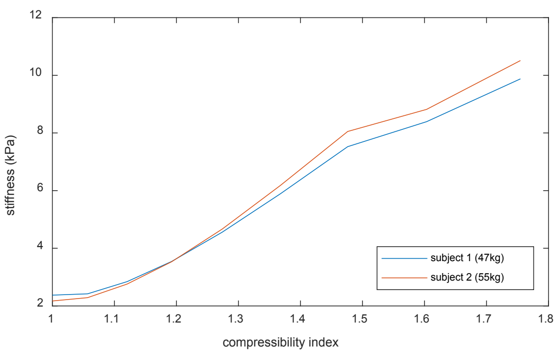


Figure 2. The positive relation between stiffness and compressibility index



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Exercise as a mechanical trigger followed by collagenase injections replicating intrinsic factors: an evolution of the animal model of chronic Achille's tendinopathy

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Introduction: Our study aimed to develop a novel animal model of Achilles tendinopathy by comparing histologic and functional findings from rats subjected to mechanical and chemical stresses.

Methods: Sixty-four Sprague-Dawley rats were divided into 4 groups (n=16): isolated treadmill running (iTR) protocol (15 degree uphill running, 20m/min, 1hr/day, 3 wks duration, wks 2-4); isolated collagenase injections (CIs) (0.1mg ea, 3 total, wks 5-7); treadmill protocol (wks 2-4) followed by 3 consecutive CIs (wks 5-7) (TCI); and controls, no running and 3 injections of NS (wks 5-7). Five animals from each group were sacrificed at weeks 8 and 10, and six animals from each at week 12. Gait analysis was performed at weeks 1 (after acclimation), 5 (following running protocol), 8 (following injection protocol) and 12 (just before latest sacrifice time-point). Histologic findings were assessed by the Movin Tendinopathy Score (8 parameters, scored from 0-3, total score 0-24). Gait parameters included stand and swing times, stride length, duty cycle and swing length.

Results: After 8 weeks, significantly increased tendinopathic scores ($p<0.001$) were found in animals subjected to iCIs (16, CI 13.1-18.9) and TCI (17.4, CI 14.4-20.3), as compared to controls (1.6, CI -1.3-4.50) and running (3, CI 0.1-5.9). After 10 weeks, significantly increased scores were found in the same groups, with slight severity regression: controls (1, CI -0.8-2.8), running (2.2, CI 0.4-4.0), collagenase (10, CI 8.2-11.8) and TCI (17.6, CI 15.8-19.4). After 12 weeks, collagenase group showed reversion of findings (3.3, CI 1.6-5.1) and wasn't different than control (2.1, CI 0.4-3.9) and running groups (2.5, CI 0.3-4.7). However, significantly increased pathological findings were noted in the TCI group (20.0, CI 18.2-21.8) consistent with chronic tendinopathic process.

Discussion: Our results indicate that sequential mechanical and chemical stresses better replicate the findings of human chronic Achilles tendinopathy as compared to either alone.

Relevance: Our novel animal model of Achilles tendinopathy using sequential mechanical and chemical stresses better approximates the human chronic Achilles tendinopathic processes than current methods.

Figure 1. Tendinopathy movin scores.

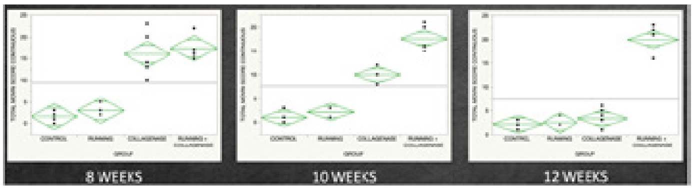
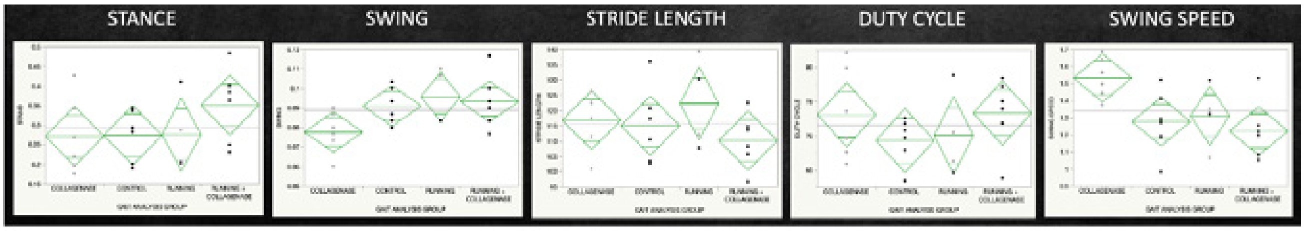


Figure 2. Gait analysis parameters at 12 weeks.



Eye-foot coordination in normal aging and mild cognitive impairment (MCI)

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Background

Mild cognitive impairment (MCI) presents as a continuum of changes of normal aging and symptoms of early Alzheimer's disease, not only in terms of cognitive functions, but also changes in motor control [1], including deficits in gait or balance [2]. Ankle joint coordination is involved in the control of gait and balance. However, how eye-foot coordination changes in MCI is unclear.

Methods

Sixty-four subjects (MCI n:24, healthy controls (CG) n:40, mean±SD: 81.6±2.1 yrs) participated in this study. The Montreal Cognitive Assessment (MoCA) was used to determine groups. Eye-foot coordination was analyzed using self-constructed pedals equipped with a linear potentiometer and a starting position of 45° with respect to the horizontal floor. During plantar and dorsal flexion, the rotation of the pedals generated live control of a line on a screen placed in front of the participant. Subjects were asked to reproduce curves using their foot (right and left, separately). Each of the three tested trials consisted of 16 sine waves of different frequencies. The error of the integral was calculated in percentage.

Results

Results of the right foot showed significantly more error for MCI compared to CG (Table 1). Both groups exhibited improvement of eye-foot coordination from trial 1 to 3.

Table 1: Mean±SD of integral error (in %) at left and right foot for controls (CG) and mild cognitive impairment (MCI).

	Error left foot			Error right foot		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
CG	23.9 ± 11.5^{A}	22.2 ± 10.3^{B}	20.4 ± 10.0^{AB}	$22.3 \pm 10.3^{*CD}$	$20.2 \pm 9.9^{\alpha C}$	$19.3 \pm 9.9^{\varphi D}$
MCI	28.1 ± 9.1^{E}	25.8 ± 8.6	24.3 ± 10.3^{E}	$28.3 \pm 8.8^{*FG}$	$23.7 \pm 6.2^{\alpha F}$	$23.4 \pm 7.1^{\varphi G}$

*, α and φ $p<0.05$ of Mann-Whitney-U-Test (inter-groups) and A, B, C, D, E, F and G $p<0.05$ of Wilcoxon Test (intra-groups)

Conclusions

Afferent information from the ankle joint and coordination of the foot are essential for gait and balance control. In line with previous studies reporting alterations in control of gait and balance in MCI [1,2], our results also showed worse Eye-foot coordination for MCI compared to CG. However, this was only significant for the right foot. Eye-foot coordination and accuracy is also essential in terms of capacity to drive a car. Leaning effects within trials were identified for both groups, however, predominantly for CG. Surprisingly, MCI group was also able to improve performance over trials, although MCI is related to impaired sustained attention [3]. In contrast, another study (using a driving simulator) also showed learning capacity in MCI after a training program [4]. Future studies are needed to investigate the coupling of afferent inputs and motor responses in (pre) dementia stages.

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Factors that influence the examination of the feet in persons with diabetes

Introduction: Diabetes Mellitus is a major public health problem and, once poorly controlled, favors the development of highly disabling complications, such as diabetic foot.

Objective: To identify the factors that influence and interfere with the implantation of foot examinations as a routine during consultation with users with Diabetes Mellitus treated in primary health care in Brazil.

Method: Cross-sectional study, with data from the second cycle of the National Program for Improving Access and Quality (2013 - 2014), using the Donabedian framework, with structural information on the work processes and results regarding the satisfaction of users served in the five regions of Brazil. It was applied Pearson's chi-square proportions homogeneity tests, cluster analysis using the multiple logistic regression model, with a significance level of 5%.

Results: Despite the improvement in access to consultation with doctors (98.1%) and nurses (99.4%) in the last six months, only about 30.4% of diabetic users had their feet examined during consultation with the health teams. primary health care. As for the presence of Semmes-Weinstein monofilament in health units in the five regions of Brazil, only 32.4% of Health Units have this instrument for assessing protective sensitivity and associated with these variables weaknesses related to the lack of technical training for evaluation of the feet and the high turnover of doctors, nurses in the teams end up compromising the bond and the essential continued care for people with chronic non-communicable diseases such as diabetes, factors that negatively hinder the implantation of the foot examination as a routine in Brazil.

Conclusion: Regional differences that influence the implantation of the examination of the feet in Primary Care were associated with the qualification of access, the work process of the teams and the meeting the needs of diabetes in five regions of the country.

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Feasibility study of insole manufacturing with polyurethane material by 3D fabrication for individuals with heel spurs

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Introduction
Plantar pain in the heel region is a frequent complaint which occurs in approximately 15% of the population, being the most common cause of heel spurs associated with plantar fasciitis [1, 2]. Studies show that personalized insoles are particularly effective in reducing pressure on the hindfoot and are therefore used in treating spurs. 3D printed insoles enable such customization, but it is necessary to study its feasibility [3].
Objective
To study the feasibility of manufacturing insoles by 3D printing with polyurethane material (TPU) to provide pressure relief in the spur area, and to compare their production time and cost with that of the microporous Ethyl Vinyl Acetate (EVA) insole.
Methods
This is a methodological, feasibility study. Computerized tomography images were used to develop and manufacture insoles by 3D printing. The images came from the InVesalius 3.1.1 database of the Renato Archer Information Technology Center, located in Campinas, S.P., which enabled access to 192 images of heel spurs and export the files in STL. format to project them in the Meshmixer software program.
Results
Regarding the production time, the insoles manufactured by 3D printing in TPU showed a reduction of 27% in their total average time when compared to traditional manufacturing. Regarding the manufacturing cost, a 35% reduction in price was observed using 3D printing.
Discussion
The results support the hypothesis that it is possible to produce a customized insole, with pressure relief in the calcaneus region, by printing in 3D, with reduction of cost and manufacturing time, using TPU. There was a 27% reduction in its production time and 35% reduction in its manufacturing cost. In addition, the customization of the insole allowed pressure relief in the desired region.
Conclusion
Personalized insoles produced by 3D printing can generate pressure relief in the heel region, have a lower manufacturing cost and shorter production time.

Table 1. Relationship between time and production steps.

Manufacturing – Traditional method	
Steps	**Time**
Negative mold	00:45
Positive mold	00:32
Cut EVA insole	00:25
Mold 6mm Plastazote	01:30
Mold 1mm Plastazote	01:10
Mold 0.5mm Plastazote	00:50
Sanding	00:20
Open spur relief orifice	00:05
Add plastazote to the orifice	00:10
Proof	00:45
Finishing and delivery	00:30
Total	07:02
Manufacturing - 3D printing	
Steps	**Time**
Scanning	00:20
Cleaning noise	00:30
Insole modeling	01:20
Printing	02:10
Proof and delivery	00:45
Total	05:05

Figure 1. Modeled heel spur insole.

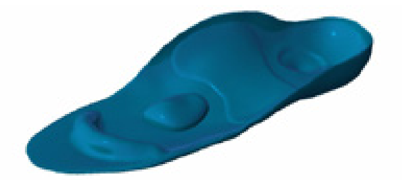

Table 2. Relationship between time and production steps.

Manufacturing – Traditional method			
Materials	**Unit**	**Quantity**	**Cost**
Plastered bandage 100 mm	Unit	2	R$3.60
Plaster - Quick Dry	Kg	2.5	R$1.10
Microporous beige/black (EVA) 6mm	m²	0.4	R$15.50
Common Plastazote 6.0 mm 1.00X1.00	m²	0.2	R$10.50
Common Plastazote 1.0 mm 1.00X1.01	m²	0.2	R$8.00
Common Plastazote 0.5 mm 1.00X1.02	m²	0.4	R$7.50
Total			R$46.20
Manufacturing - 3D Printing			
Materials	**Unit**	**Quantity**	**Cost**
TPU	Kg	200	R$30.00
Total			R$30.00

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FEM driven workflow for virtually optimized insole

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Background

Foot deformities and biomechanical alterations lead frequently to abnormal loading patterns. Customized insoles are usually prescribed to treat or prevent these problems by reducing excessive plantar pressures (PP) or providing stability, realign the foot arch, distributing weight, increasing the contact area, and comfort [1]. State-of-the-art in orthotics production is represented by digital scanning and computer aided surface modeling techniques. However, to date, insoles design is commonly determined by the experience of the orthopedic technician who still prefer to use traditional plaster cast methods [2]. A computational approach, such as the finite element modelling (FEM), could provide a quantitative estimation of the benefit of the plantar foot orthotics in term of soft tissue deformation, PP and internal stresses according to the insole shape and material [1]. The aim of this study was to propose a methodology for testing the produced insole.

Methods

The foot geometry of a child with flat foot (age 12 years, shoe size 42, BMI 28.5 Kg/m^2) was capture with a 3D scanner. Foot bones geometry was segmented from a previously acquired flat foot MRI [3] (Simpleware). Two insoles geometries were compared: one proposed by the CAD-CAM software and one designed by the orthopedic technician. Geometries were meshed with tetrahedral elements (pipeline in Figure 1) and material properties were assigned according to the literature [3] and to the material characteristics declared by the insole manufacturer. The vertical loads acquired during gait on a treadmill (5 km/h) through a PP insole system (PedarX, Novel gmbh) were applied in the FEM as boundary conditions. Loading response and midstance phases of the gait cycle were simulated [3] in 3 conditions: without and with the two insoles. The comparison between the experimental PP and the simulated ones (peaks and distribution) was used for validation purposes. Both simulated PP and internal Von Mises stresses in plantar soft tissues were compared across the different conditions.

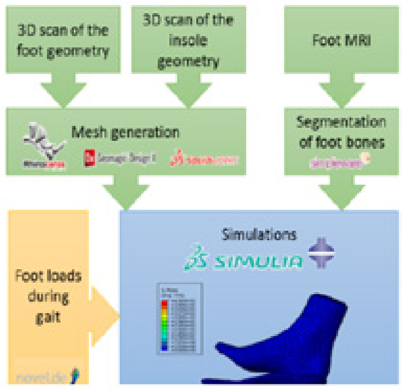

Figure 1. Pipeline for the FEM creation.

Results

A good agreement was reached between the experimental and the simulated PP (Figure 2). Simulated insole did not completely succeed in assuring a better distribution of the PP but they reduced the Von Mises stresses, particularly the insole designed by the technician.

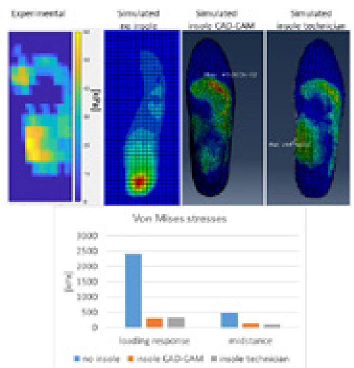

Figure 2. PP maps and Von Mises stresses values

Conclusions

The behavior of the insole was successfully simulated through the proposed pipeline by adopting experimentally acquired subject-specific geometry and loads: this can be used to predict the effects of the produced insole on the foot function thus resulting in an efficient tool for optimizing its design.

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Fine-wire electromyography of the transverse head of adductor hallucis during locomotion

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Background:
Advanced measurements and imaging modalities have increased our understanding of the complexity of human feet, including their elastic energy storage [1], passive mechanics [2], and function [3] during limb loading and ambulation. Although these studies provide insight into the biomechanical contributions of muscles across the medial longitudinal arch; the forefoot musculature, including the functional role of the adductor hallucis, has remained largely ignored. Previous literature on the transverse head of adductor hallucis (AddH-T) has largely focused on muscle morphology [4]. The role of the AddH-T, which runs parallel to the distal transverse metatarsal arch, has never been studied using fine-wire EMG during locomotion. The purpose of this study is to explain a novel method of recording fine-wire electromyography (EMG) of the adductor hallucis muscle of the foot, and secondly, to report phasic AddH-T muscle activity during level walking on hard and soft surfaces.

Methodology:
Ultrasound-guided fine-wire EMG (Noraxon Ultium) was recorded from the AddH-T of each foot, in ten asymptomatic young adults (23.2±5.2years). Participants completed ten walking trials on a 10 meter custom-built platform. Removeable platform inserts, which remained flush to the walking surface, were placed over 3 force plates (AMTI, Waterdown, MA), and manipulated in each experimental condition (hard and soft surface). Ensemble averages were calculated from the time normalized linear-enveloped EMG from each participant (represented from 0 to 100 percent of the gait cycle).

Results:
Using the described ultrasound-guided fine-wire protocol (Figure 1A & B), successful EMG signals were generated in 19 of 20 feet. When walking over hard or soft flooring, the AddH-T muscle has two bursts in EMG, occurring between 0-20% and 50-65% of the gait cycle (Figure 2). The magnitude of peak activity was often reduced at initial contact when walking over foam. 45% of participants experienced a third burst in EMG activity at midstance, corresponding to 30-40% of the gait cycle.

Conclusion:
This study has successfully explained a novel method of recording fine-wire EMG of the adductor hallucis (transverse head) muscle of the foot. Results suggest that the AddH-T may isometrically stabilize the forefoot at initial contact and toe-off, while further anchoring the hallux during propulsion. These results provide preliminary insight into the functional role of the AddH-T during human locomotion.

Figure 1. Visual representation of the target location of fine-wire insertion into the transverse head of adductor hallucis. **A.** Superficial musculature on the dorsum of the foot. Fine-wire insertion occurred between digits III and IV, through the dorsal interossei muscle (blue), medial to the tendon of the extensor digitorum longus (red). **B.** Deep layer of musculature on the dorsum of the foot. The target insertion site into AddH-T (red), remaining medial to the plantar interossei (blue).

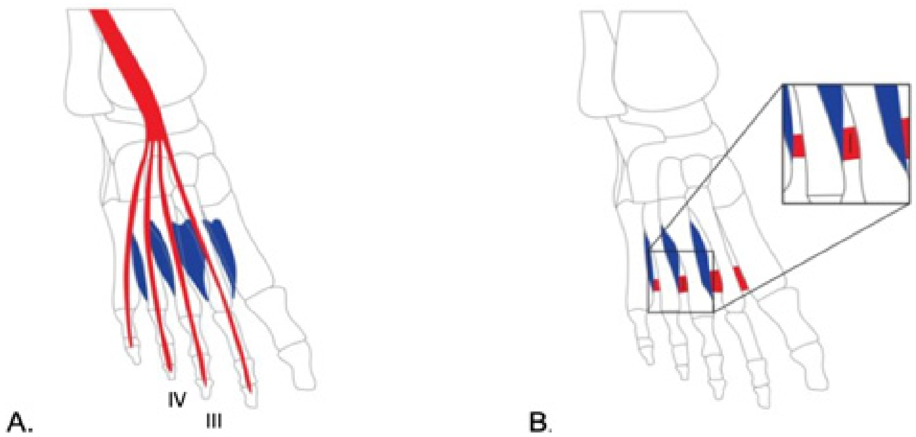
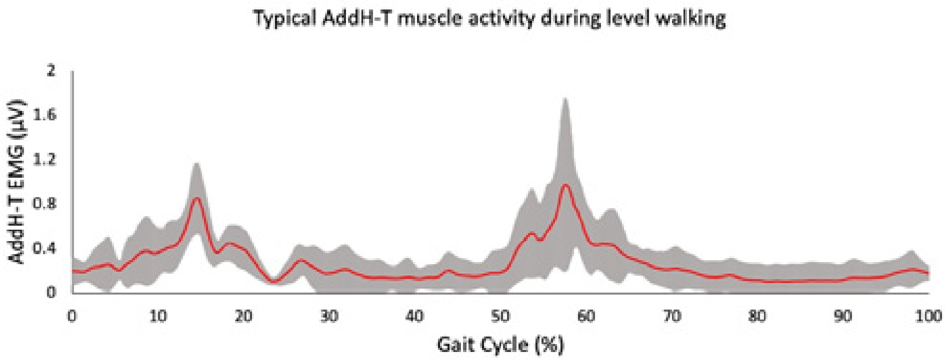


Figure 2. Typical EMG activity of the transverse head of the AddH-T muscle during the gait cycle (initial foot contact (0%) to next same foot initial foot contact (100%)).



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Foot alignment in symptomatic National Football League (NFL) athletes: a weightbearing CT analysis

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Introduction: Weightbearing Cone Beam Computed Tomography (WBCBCT) allows 3-dimensional imaging of the foot during stance. Our aim was to describe the foot alignment in National Football League (NFL) players with different symptomatic foot and ankle pathologies using WBCBCT. We compared them with normally aligned controls and determined if any predominant morphotype could be identified.

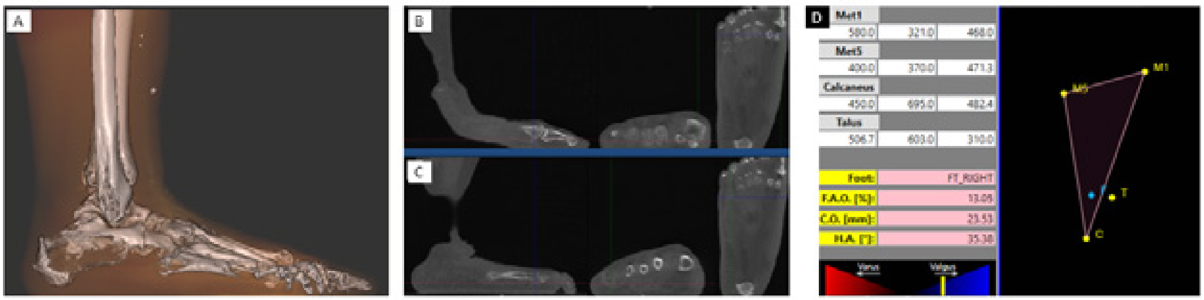
Methods: Forty-one feet from 36 active NFL players (mean age 24.9 years, range 16-35) were assessed using WBCBCT and compared to 20 normally aligned controls from normal population. Measurements included: Foot and Ankle Offset (FAO); Calcaneal Offset (CO); Hindfoot Alignment Angle (HAA); angle between inferior and superior facets of the talus (Inftal-Suptal); angle between inferior facet of the talus and the horizontal/floor (Inftal-Hor); Forefoot Arch Angle (FAA); navicular-to-floor distance; medial cuneiform-to-floor distance.

Results: NFL athletes showed a neutrally aligned hindfoot when compared to controls (FAO mean value at 1% vs 0.5%, CO at 2.3 mm vs 0.8 mm and HAA at 2.9° vs 0.8° in two groups, with all $p > 0.05$) and a normal morphology of the subtalar joint (no difference in Inftal-Suptal and Inftal-Hor angles). Conversely, in these athletes we found a decreased medial longitudinal arch (FAA at 15° vs 18.3°, *p* 0.03) with smaller navicular (38.2 mm vs 42.2 mm, *p* 0.03) and medial cuneiform (27 mm vs 31.3 mm, *p* 0.01) mean distances to the floor when compared with controls.

Discussion: In our series, NFL players presented with a lower medial longitudinal arch when compared to controls but a neutrally aligned hindfoot.

Relevance: WBCBCT may help shed light on anatomical risk factors for injuries in professional players and to plan specific prevention programs.

Figure 1.



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Foot structure and lower limb function in individuals with midfoot osteoarthritis: a systematic review

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Abstract
Background: Midfoot osteoarthritis (OA) is characterised by arthritic change in one or more joints of the midfoot [1] occurring in 12% of people aged over 50 years [2]. Mechanical factors, such as higher midfoot plantar pressures during walking [3, 4] and a flatter foot posture [5, 6], have been implicated in the development of midfoot OA, and may have a negative impact on physical function [7]. Therefore, understanding how foot structure and function (such as alignment, range of motion or dynamic function) differ between people with and without midfoot OA will assist in elucidating the underlying mechanisms responsible for its development, and inform treatment decisions. Therefore, the aim of this systematic review was to determine how foot structure and lower limb function differ between individuals with and without midfoot OA.
Design: Electronic databases were searched from inception until May 2020. To be eligible, studies needed to (i) include participants with radiographically confirmed midfoot OA, with or without midfoot symptoms, (ii) include a control group of participants without radiographic midfoot OA or without midfoot symptoms, and (iii) report outcomes of foot structure, alignment, range of motion or any measures of lower limb function during walking. Screening and data extraction were performed by two independent assessors, with disagreements resolved by a third independent assessor. The methodological quality of included studies was assessed using the National Institutes of Health Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies.
Results: A total of 1,550 records were screened by title and abstract and 11 met the inclusion criteria. Quantitative synthesis indicated that individuals who had midfoot OA had a more pronated foot posture, greater first ray mobility, less range of motion in the subtalar joint and first metatarsophalangeal joints, longer central metatarsals and increased peak plantar pressures, pressure time integrals and contact times in the heel and midfoot during walking. Meta-analysis could not be performed as the data were not sufficiently homogenous.
Conclusions: There are several differences in foot structure and lower limb function between individuals with and without midfoot OA. Future research with more consistent case definitions and detailed biomechanical models would further our understanding of potential mechanisms underlying the development of midfoot OA.

Registration: PROSPERO database - CRD42020141722.

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Foot-ankle strengthening program in elderly people with knee osteoarthritis improves foot kinematics and function: a single-arm pilot study

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Background: In addition to knee joint changes, several modifications in the foot structure have been found in knee osteoarthritis (KOA) patients [1]. The foot-ankle complex is known for its ability to absorb, dissipate and return kinetic energy due to the maintenance of the arches during walking in healthy conditions [2]. Moreover, intrinsic foot muscle training was effective in improving functionality in healthy subjects [3] and in individuals with diabetic neuropathy [4]. However, little is known about the effects of foot-ankle intervention in patients with KOA. Thus, this study aimed to evaluate the effects of a foot-ankle muscles strengthening program on foot kinematics and function in KOA individuals.

Methods: Throughout a single-arm pilot study, 28 individuals diagnosed with KOA were contacted for scheduling and 7 were recruited based on the clinical and radiographic criteria of the American College of Rheumatology. Patients included were between 40 and 75 years, with grade II or III KOA, body mass index< 35kg/cm^2 and worst pain in the last week between 30 and 80 mm in the Visual Analogue Scale (VAS). They performed a supervised 6-weeks foot-ankle strengthening program. The medial longitudinal arch (MLA) range of motion (ROM) of the foot was measured by kinematic analysis during gait using three-dimensional displacement of passive reflective markers (9 mm) tracked with six infrared cameras (Vicon Motion Systems Ltd, Oxford, UK) and the functional performance was evaluated by 30s chair-stand test (30s), 9-step stair-climb test (9step) and 40m fast paced walk test (40m). Data was further processed using Visual3D (C-Motion Inc., Germantown, MD). All procedures were performed before and after the intervention and paired t-tests were used to compare assessments ($p<0.05$).

Results: Four subjects finished the treatment (3 men; 1 woman; Exclusions: (1) knee pain, (1) plantar fasciitis crisis and (1) could not participate). Greater MLA ROM (p=0.886; CI95%=-26.34-24.43; *d*=0.12) and better functional performance (p=0.231; CI95%=-13.89-4.89; *d*=1.04, for 30s; p=0.198; CI95%=-4.41-14.39; *d*=1.21, for 9step; p=0.278; CI95%=-0.65-0.22; *d*=0.83, for 40m) were achieved after intervention, but without statistical difference.

Conclusion: Foot-ankle strengthening program seems to improved MLA ROM and function in people with KOA.

Trial registration: NCT04154059

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FORCE-TIME CURVES AND PLANTAR PRESSURE DISTRIBUTION IN HIGH LEVEL ATHLETES OF 400 METRES HURDLES IN BLOCK PHASE

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Introduction

The 400 metres hurdles race requires speed, endurance, strength and technique. Despite this, according to coaches, the block phase is not frequently trained and there is a lack of studies about such a phase. Papers regard 100 metres block start [1,2,3,4] reinforce that the time gain in that phase is very relevant. Thus, it is necessary to develop specific methods for analyzing the individual performance of 400 metres hurdles athletes. No previous study was found in the literature approaching the matter.

The aim of this work was to analyze the force-time curves and the plantar pressure distribution inside footwear of national level athletes of 400 metres hurdles during the block phase. The *rationale* of the study was to analyze the intra and inter subject variability aiming to identify the presence or not of similar patterns of force-time curves and pressure distribution.

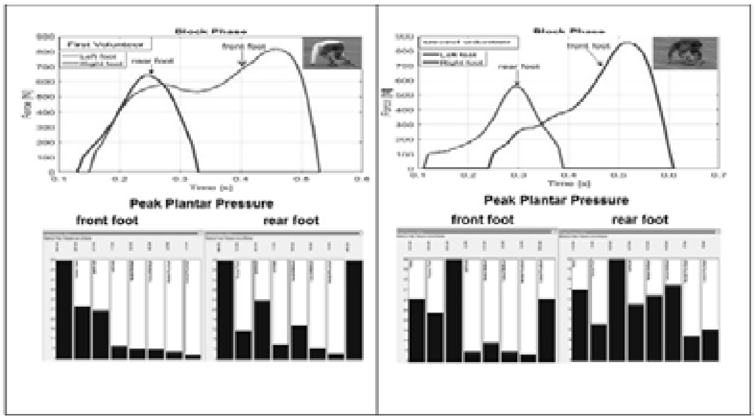
Methods

Five national level 400 metres hurdle athletes were analyzed in training conditions during the competition phase. The Pedar®-X plantar pressure distribution analysis system (Novel, Germany) was used to data collection. The system consists of two synchronized insoles instrumented with 99 pressure sensors (100Hz). Each athlete performed two full speed simulated runs, from the block start until the eighth obstacle, with 20 minutes of rest interval between trials. The software provided the total force in each insole and the pressure distribution according to eight regions. A Matlab® function was designed to treat and analyze data. Force-time curves and pressure distribution of each individual were analyzed and compared.

Results

Figure 1 shows an example of comparison between two volunteers in terms of force-time curves and pressure distribution along the block phase of 400 metres hurdles. The force-time curves of left and right feet (rear and fore legs) present two dissimilar shapes. The same can be seen in the plantar pressure distribution canvas. This dissimilarity remained when comparing the two trials of the same athlete and across subjects.

Figure 1. *Total force-time curve (Top) and plantar pressure distribution (Bottom) of rear and fore foot two different volunteers during the block phase of 400 metres hurdles race.*



Discussion and Conclusion

The results of the present study revealed an absence of a clear pattern among the evaluated athletes as expected when the technique is clearly established and well trained. In conclusion, our results also suggest that those 400 metres hurdles athletes could improve their performance by defining and further training an optimal block strategy.

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Forefoot subdivision and kinematics for clinical gait analysis

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Introduction: Multi-segment foot models are often used in clinical gait analysis for the diagnosis and treatment planning of a wide range of musculo-skeletal disorders of the lower-limb. Currently, there exist 39 different protocols that track and measure the kinematics (and kinetics) of the foot during walking for both clinical and research purposes [1]; each differs in terms of segmentation, marker placement, kinematic convention, and other factors [2]. While it may be appropriate to make a rigid body assumption about lower-limb segments such as the femur and tibia, whether it is suitable to treat the forefoot as a single rigid segment remains questionable. A preliminary study [3] using rigidity as a criterion [4] has provided guidance on how the forefoot could be divided Based on these recommendations, the primary aim of this study was to propose and explore the kinematics of a new forefoot model in comparison to a unified forefoot segment .

Methodology: An earlier investigation by Chan et al. [3] recommended that the forefoot could either be divided into two segments, a medial segment (1st through 3rd metatarsals) and a lateral segment (4th and 5th metatarsals); or a three-segment model where the 1st and 5th metatarsals are independent units and the 2nd through 4th metatarsals (intermediate forefoot segment) comprise a single segment. Based on these results, a hybrid forefoot model has been developed to capture the motion of all these segments simultaneously. The kinematics of all forefoot segments were measured and compared to the results obtained from a unified forefoot (the original Oxford Foot Model, OFM [5]) using walking data collected from forty-five normal healthy adults (age = 27.67.0 years, 25 males and 20 females) using a sixteen-camera motion capture system (Vicon Motion Systems, Oxford, UK). Differences in the kinematic output were reported based on visual identification and unpaired t-tests for the descriptive statistics (mean angle, range of motion, etc.).

Results: The largest visual differences in the kinematics between the individual sub-divided forefoot segments were observed in the transverse plane, in particular, between the medial and the lateral forefoot segments. From 45-60% gait cycle, the medial forefoot progressively abducted about 6° whereas the lateral forefoot first adducted for about 5°, followed by a rapid abduction of 5°. On average, the motion of the subdivided segments was larger than the OFM forefoot segment in all three planes as indicated by increased ranges of motion. This implies that treating the forefoot as a unified segment effectively averages out the ranges for the medial and lateral segments.

Conclusions: An alternative protocol to measure the biomechanics of the forefoot in greater detail has been proposed. Several unique motion patterns were identified in this novel forefoot model that were previously not observed in a unified forefoot segment. In addition, this research has contributed to the evidence that, if detailed forefoot motion is required clinically, the forefoot should not be treated as a single segment.

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Functional implications of the flat-topped talus following treatment of idiopathic clubfoot deformity

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Introduction: The flat-top talar dome is a well-known potential consequence of both operative and non-operative clubfoot management. While it is assumed that patients with a flat-top talus will have greater problems with daily activity, the functional impact of this deformity has not been characterized in the literature. The purpose of this study is to analyze the relationship between talar dome morphology and ankle function at skeletal maturity in patients treated for idiopathic clubfoot deformity during infancy.

Methods: 33 skeletally mature patients (average age 17.9 years, SD 1.6 years) with 52 idiopathic clubfeet were identified from our institution's clubfoot registry. Plain weight bearing lateral foot films, gait analysis and patient reported outcomes (PRO) using the Pediatric Orthopaedic Data Collection Instrument (PODCI) were obtained in all patients. Radius of curvature (ROC) of the talar dome and tibial plafond were measured along with numerous other parameters of talar and calcaneal morphology. All measurements were correlated to PODCI scores and gait analysis data.

Results: Patients demonstrated marked variability in ROC of the talar dome (mean 33.1mm, SD 19.6 mm), talar dome radius to talar length (R/L) ratio (mean 0.60, SD 0.39), opening angle of the talar dome (alpha angle) (mean 88.7°, SD 29.5°) and incongruity in the ROC between the talar dome and tibial plafond (TD/TP ratio) (mean 1.17, SD 0.44). Increased TD/TP ratio correlated negatively with maximal plantarflexion (PF) (r=0.404, p=0.005), ankle range of motion (ROM) (r=0.383, p=0.008) and maximum power generation during step off (r=0.381, p=0.008). A less acute alpha-angle correlated positively with PF (r=0.404, p=0.005), ankle ROM (r=0.383, p=0.008) and maximum ankle power generation (r=0.381, p=0.008). Lower ROC of the of the talar dome correlated with increased maximum power generation (r=0.326, p=0.025). Increased R/L and TD/TP ratios correlated negatively with PODCI happiness domain scores (r=-0.353, p=0.044; r=-0.377, p=0.025, respectively) while talar length correlated with higher happiness domain scores (r=0.393, p=0.024), higher global function scores (r=0.360, p=0.040) and lower pain scores (r=0.354, p=0.043).

Discussion: While flatness of talar dome correlates significantly with altered gait mechanics, the effects on patient reported function are more modest during the second decade of life. Further study is required to assess the longer-term effects of the flat top talus on function and joint health.

Relevance: Patient reported function was mildly correlated to flatness of the talar dome despite alternated gait mechanics.

Functional reach test: balance behavior in rheumatoid arthritis

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Background: Rheumatoid arthritis (RA) causes pain, progressive joint destruction, physical and motor capacities loss, impairing balance and increasing the falls risk [1, 2]. Functional reach test (FR) is an important method to identify subjects at risk of falls; however, its performance by individuals with RA and their balance characteristics are still unclear. The aim of this study was to determine what is the center of pressure (COP) oscillation behavior on a force platform during the performance of the FR test by RA patients; and which, among the biomechanical parameters, are predictors of falls. *Methods*: Twenty-nine women with RA and 16 non-RA (CG) were matched by age. Participants told their demographic characteristics and medical history. Disease activity (DAS-28) and anthropometric measurements were assessed. Balance confidence and functional capacity were measured by the Activities-specific Balance Confidence Scale and the Health Assessment Questionnaire. All participants reported on how many falls they had the last year. An FR test while standing barefoot on a dynamometric platform was conducted to calculate maximum displacement and velocity of the COP. Differences between the groups considering COP parameters were analyzed with MANOVA. Poisson's multiple regression analysis was conducted to correlate COP parameters with the falls. *Results*: Individuals with RA presented lower COP (in the anterior-posterior direction) and COP mean velocity (in both directions), which indicates that while performing FR tasks, body displacement is avoided to diminish velocity and body swing, thus, postural control is mainly conducted with ankle strategies and closed-loop feedback mechanisms. It is supposed that due to the chronic pain, joint destruction, and neuroinflammation, there is an inefficient adjustment of the functional interaction of open-loop and closed loop neuromuscular systems, promoting impaired postural responses. COP (anterior-posterior direction) were shown to be positively correlated and COP (right and left directions) were shown to be negatively correlated to the self-reported number of falls. *Relevance:* This study highlights that during reach task, rheumatoid arthritis decreases both: anterior-posterior swing and COP velocities and, do not affects mediolateral displacement. COP amplitudes are predictors of self-reported number of falls. COP (anterior-posterior direction) were shown to be positively correlated, and COP (right and left directions) were shown to be negatively correlated to the self-reported number of falls.

Ackwnoledgements: Authors gratefully acknowledge CAPES, CNPq and FAPESC for funding and PhD fellowship .

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Gait analysis driven cluster analysis of diabetic patients: novel subgroups and their association with clinical outcomes in 15-years follow up

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Background

The global prevalence of diabetic foot is 6.4% and is expected to increase. Lifetime risk of diabetic foot ulcers ranges from 15% to 20% [1]. Diabetic foot is a multifactorial complication; its risk factors are peripheral neuropathy (PN), peripheral vascular disease, limited joint mobility, foot deformities and others related to the patient's general condition, such as poor glycemic control and improper foot care [1]. Other associated factors are the alterations of biomechanical parameters during gait. The aim of this study is to compare two approaches for patients' classification, based on cluster analysis of gait parameters in a 15-years clinical follow up study.

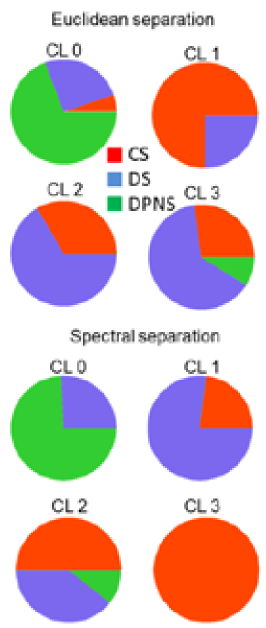

Figure 1. Subjects grouping in the 2 clustering methods.

Methods

Twenty-one control subjects (CS - mean(± SD) age 61,3±4,4 years and BMI 24,5±2,4 kg/m^2), 30 diabetic subjects (DS - age 61,5±9 years and BMI 26,9±2,9 kg/m^2) and 29 DS with PN (DPNS - age 61.7±8,9 years and BMI 25,5±2,9 kg/m^2) took part in the study. They signed informed consent and undertook clinical examination and gait analysis by means of a stereophotogrammetric system (BTS) synchronized with two force plates (Bertec) [2]. Several self-selected speed gait trials were acquired and 3D trunk, pelvis, hip, knee and ankle joint angles and moments and 3D ground reaction forces were extracted bilaterally [2]. Each subject was represented by 280 points: left and right values for each variable were averaged for noise reduction. On these representation, 2 clusters analysis approaches were compared: 1) Euclidean separation (ES), where K-means cluster algorithm was applied with Euclidean distance and K-means++ as initialization step; 2) Spectral separation (SS) with extraction of the spectral components on a 100-point windows of each subject and then ES procedure on the spectral components. A code was implemented in C++ and the MLPACK and FFT3 libraries for clustering and spectral analysis were used respectively. Each cluster was also characterized in term of clinical data as in [2].

Results

The SS lead to better separated clusters than ES (Figure 1-top and bottom respectively, CS (red) and DPNS (green) in cluster 3 and 0). Here subjects with higher prevalence of diabetic complications and foot deformities where grouped together (Figure 2). DS (blue) associated to cluster 2 displayed gait patterns similar to DPNS.

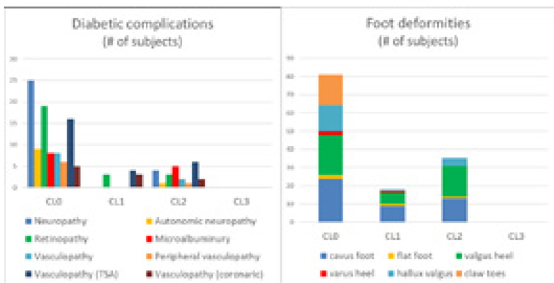

Figure 2. Clinical data for the clusters obtained with the SS method.

Conclusions

An objective classification of DS with and without PN was achieved, driven by gait parameters. This approach could be used to develop targeted therapies aiming at preventing diabetic foot complications.

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Gait coordination analysis in young sedentary and practitioners at different speeds using a modified vector coding technique

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1. Introduction

The aim of the present study is to analyze the variability of segmental coordination during gait of young sedentary and practitioners at different speeds (preferred walking speed (PWS), 120% of PWS and 80% of PWS) through vector coding technique (VC). The phase angles represent the pattern of segment coordination, while the standard deviation of the phase angle at each point in the gait cycle represents the variability of segment coordination [1]. In this study the entire time series was used: a total of 25 gait cycles for all participants.

2. Methods

Thirty young adults, 15 sedentary and 15 practitioners participated in the study. Young adults were classified as practitioners if they practice physical activity at least three times a week, one hour a day. All participants executed a protocol with three 1-min walking trials on a treadmill at each speed, in a randomized order. For leg and foot right segments pair (ankle joint), angles were computed during four gait phases: first double support, single support, second double support and swing phase. Kinematic data was exported as txt file and analyzed with a custom MatLab code (R2018a, MathWorks, Natick, MA).

3. Results and discussion

There was no significant main effect of groups, and no significant interaction effect between groups and speeds. However, significant main effects of speed were observed, as shown in Table 1. These preliminary results suggest that leg and foot coordination variability during push-off phase, and during swing phase, are speed dependent showing that, although these segments are in phase, their coordination variability differs.
The results are shown in the Table 1 below.

Table 1. Coordination variability of leg-foot pair.

Effect	Phases of Gait	F	p	ἀ
Speed	First Double Support	3,880	NS	0,217
	Single Support	3,924	NS	0,219
	Second Double Support	26,725	0,000	0,659
	Swing	15,228	0,001	0,521

Mixed repeated measures ANOVA. F is used to test the overall fit of a regression model to a data set; p is the significance of the test; ἠis a measure of the size of the effect; NS = Not Significant.

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Ground reaction force and plantar pressure responses in racing and training shoes submitted to usage

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Introduction: Racing shoes have some differences in their construction when compared to Training shoes [1]. Therefore, it is important to investigate what differences Racing shoes present in their kinetic responses when submitted to some use. The aim of this study is to examine the influence of usage on Ground Reaction Force (GRF) and plantar pressure parameters on Racing and Training shoes.

Methods: Nine running shoes were used in this study: three Racing shoes model 1 (R1), three Racing shoes model 2 (R2) and three Training shoes (T). All models used EVA foam of similar density. The main difference between the running shoes was the lighter mass that the racing shoes had in comparison to the training shoe and some specific features that each brand incorporated in their models. The data collection occurred when the shoes were new and after 100km, 200km and 300km of use. The usage was promoted by the three experienced long distance runners. The GRF was collected by the Gaitway Instrumented Treadmill System (First peak and Loading Rate) and Plantar Pressure by the F-Scan system (Contact area and Peak pressure). A two-way analysis of variance (ANOVA) with repeated measurements was applied, followed by a Tukey HSD post hoc test.

Results: Some variation occurred in first peak and loading rate values, but no systematic changes were observed in all running shoes along usage. On Contact Area and Plantar Pressure values, the differences were more shoe dependent than on GRF values. Total contact area did not change in R1 and T, but did systematically increased in R2 after 100km and remained similar through other conditions. On Peak Pressure values no increase could be observed in any of the regions analyzed, in fact the Peak Pressure values remained similar or decreased with usage. The pressure values were more influenced by the factor shoe type than mileages of use.

Discussion

GRF and Plantar Pressure measurement can indicate cushioning characteristics of the shoe [2, 3, 4]. Some evidence indicates material deterioration, less efficient cushioning and increase in peak pressure values with increased usage [5]. Racing shoes did not present systematic alterations in kinetic responses along usage as was expected, these results suggest that the durability of Racing could be greater than 300 km.

Relevance:

Apparently, racing shoes could have a durability superior a 300km. The classification of racing shoe may not be sufficient to indicate a lower durability.

Trial registration

This project and the experimental procedure were approved by the local Research Ethics Committee (protocol n. 65).

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Hallux valgus deformity in patients with adult acquired flatfoot deformity: a weightbearing CT study

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Introduction: Longitudinal arch collapse and first ray instability represent landmarks for adult acquired flatfoot deformity (AAFD) and have been linked to the development and progression of hallux valgus (HV)[1]. The aim of this study was to use WBCT to assess the correlation between hallux valgus severity and traditional indicators of foot collapse in patients with AAFD.

Methods: In this retrospective comparative study, we included 108 patients with stage II AAFD, 36 men and 72 women, mean age 54.4 (range, 20-18) years. WBCT images were evaluated by two blinded and independent board-certified foot and ankle orthopedic surgeons and the following data was harvested: 1-2 intermetatarsal angle (IMA), HV angle (HVA), talocalcaneal angle (TCA), talus 1st metatarsal angle (T1-MA) in axial and sagittal planes, hindfoot alignment angle (HAA), hindfoot moment arm (HMA), navicular- and medial cuneiform-floor distance (NCFD and MCFD, respectively), and talonavicular uncoverage angle (TUA). Statistical analysis was performed using Pearson's correlation, intraclass correlation coefficient, and multiple regression analysis. P-values less than .05 were considered significant.

Results: We found overall good to excellent intra- and interobserver reliability (range, 0.65-0.99) for WBCT measurements. IMA and HVA measurements were significantly correlated with each other ($p<.0001$, $R^2=.736$). IMA significantly correlated with increased TCA ($p<.0001$), T1-MA in axial plane ($p=.0001$), and HMA ($p=0.0049$). HVA significantly correlated with increased MCFD ($p=.0183$), T1-MA in both axial ($p=.004$) and sagittal planes ($p=.0036$), and TUA ($p=.0035$). The only AAFD measurements that were not significantly correlated with IMA or HVA were HMA and NCFD.

Discussion: To the best of our knowledge this is the first study to confirm the association between AAFD, first ray instability and hallux valgus deformity using WBCT images. Our study results demonstrated that stage II flatfoot patients have increased intermetatarsal and hallux valgus angles. Most of the AAFD measurements evaluated were significantly associated with either increased IM or HV angles.

Relevance: Foot and ankle surgeons should consider these findings during the evaluation and surgical planning of patients with AAFD. Additional evidence that hallux valgus should be treated concomitantly with AAFD given the correlation between conditions.

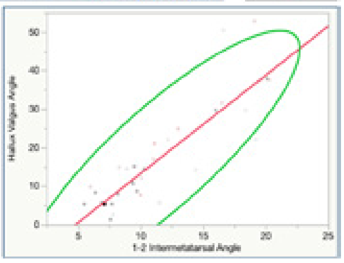
Figure 1. Analysis of hallux valgus deformity in patients with adult acquired flatfoot deformity using weightbearing CT.

1-2 Intermetatarsal Angle Multilinear Regression with AAFD Measurements

AAFD Measurement	Mean ± SD	P-Value
Talocalcaneal Angle Axial Plane	26.0°±10.3°	0.00006
Talus - First Metatarsal Angle Axial Plane	19.0°±13.6°	0.00011
Hindfoot Alignment Angle	22.3°±12.9°	0.00491

Hallux Valgus Angle Multilinear Regression with AAFD Measurements

AAFD Measurement	Mean ± SD	P-Value
Medial Cuneiform - Floor Distance	15.1mm±5.5mm	0.01832
Talus - First Metatarsal Angle Axial Plane	19.0°±13.6°	0.00040
Talus - First Metatarsal Sagittal Axial Plane	15.7°±8.8°	0.03514
Talonavicular Uncoverage Angle	17.8°±13.9°	0.00358



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Heel rise task identifies midfoot function during walking in diabetes

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Background: Midfoot deformity in people with diabetes mellitus and peripheral neuropathy (DMPN) may lead to ulceration and amputation [1, 2]. The amount and timing of midfoot function (forefoot on hindfoot motion) during single-limb heel rise has the potential to identify abnormal midfoot function during walking that could contribute to deformity. The purpose of this study was to determine the relationships of midfoot motion and ankle power during heel rise to walking in people with and without DMPN.

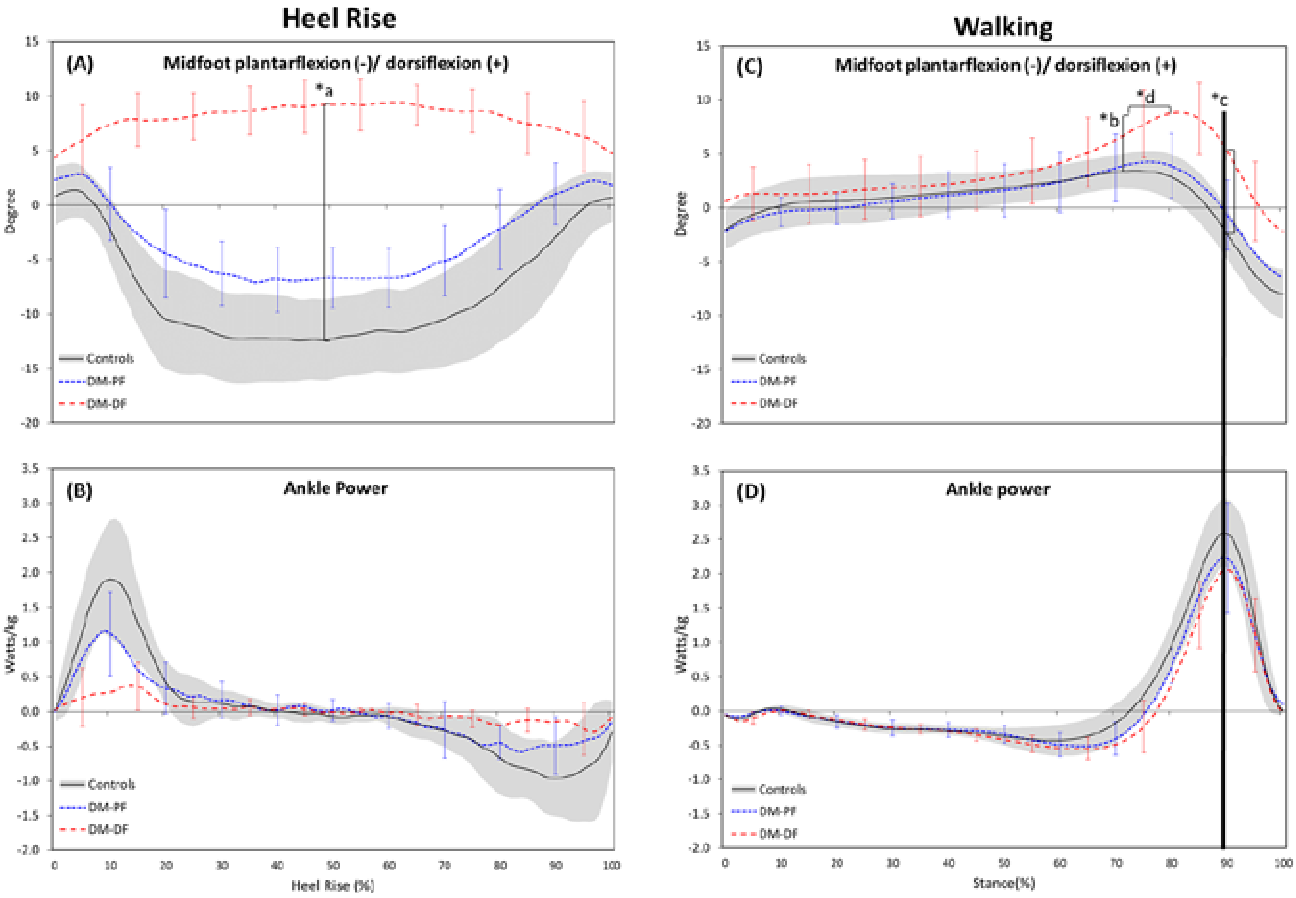
Methods: Single-limb heel rise and walking midfoot dorsiflexion/plantarflexion and ankle plantarflexor power were collected and analyzed on 59 people with DMPN and 20 controls without DMPN. Twelve DMPN with the best midfoot function (most plantarflexion; DM-PF), 12 DMPN participants with the worst midfoot function (most dorsiflexion; DM-DF), and 12 controls with the best midfoot function during heel rise were compared to better understand differences in midfoot function during walking. Pearson correlation examined the relationship of heel rise and walking variables. One-way analysis of variance and least significant difference post hoc test was conducted to detect the difference among groups.

Results: Midfoot plantarflexion at peak heel rise and at peak ankle power during walking was correlated in the total group ($n=79$, $r=0.68$, $p<0.01$). At peak heel rise, midfoot plantarflexion was greatest in controls [mean (SD): -14°(4)], and progressively less in DM-PF [-8°(3)] and DM-DF [8°(3); $p<0.01$, Figure 1 (A)*a]. DM-DF had greater midfoot dorsiflexion during the stance phase (Figure 1 (C)*b) and at peak ankle power (Figure 1 (C)*c) compared to controls and DM-PF ($p<0.05$). Peak ankle power during heel rise and walking was correlated in the total group ($n=79$, $r=0.45$, $p<0.01$). The percent of stance at which peak ankle power occurred was not significantly different among groups ($p=0.71$). However, peak midfoot dorsiflexion occurred later in stance in the DM-DF compared to controls and DM-PF ($p<0.01$; Figure 1(C)*d).

Discussion: The heel rise task identified midfoot function during walking in people with and without DMPN. DM-DF group not only performed midfoot dorsiflexion instead of plantarflexion during heel rise, but also failed to plantarflex during walking. Inability to plantarflex the midfoot limits the ability of the foot to transform into a rigid lever for efficient transmission of plantarflexor force during walking.

Conclusion: Prolonged dorsiflexion during stance and increased dorsiflexion range during push-off phase of walking may contribute to developing midfoot deformity increasing the risk of plantar ulceration in people with DMPN.
Acknowledgment: This study was funded by the National Institute of Diabetes and Digestive and Kidney Diseases of the National Institutes of Health (R01 DK107809).

Figure 1. Midfoot sagittal plane motion and ankle power during heel rise and walking. Shaded band shows the mean ± standard deviation for the control group. Dotted line (blue) is mean for the DM-PF group, dotted line (red) is mean for the DM-DF group, and solid line is mean for the control group. The black vertical line in graph (B) indicates the percent of stance at which peak ankle power occurred. (A)*a: Peak midfoot plantarfleixon during heel rise: Control > DM-PF > DM-DF. (C)*b: Peak midfoot dorsiflexion during stance, DM-DF > control ≈ DM-PF. (C)*c: Midfoot dorsiflexion at peak power, control ≈ DM-PF > DM-DF. (C)*d: peak midfoot dorsiflexion occurred later in DM-DF compared to controls and DM-PF.



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High Resolution 3D Weight Bearing Imaging of Foot & Ankle: Implications for Near Term and Long-Term

Abstract

Post-traumatic syndesmotic injuries are very common in ankle joint, that typically present clinically without specific findings during the initial physical examination. They have been reported in approximately 18% of ankle sprains and up to 23% ankle fractures. If remained untreated, syndesmotic injuries can lead to chronic instability and ultimately secondary tibiotalar osteoarthritis (OA). This review session will focus on novel High resolution ankle MRI for specific findings relevant to syndesmotic injury. In addition we will focus on high-quality 3D weight-bearing (WB) CT imaging for early detection of biomechanical derangements associated with syndesmotic injuries. We will discuss the diagnostic accuracy and reliability ("near-term results") and the association between the WB-CT measurements and early CT features of tibiotalar OA ("long-term results").

How different is xrays and WBCT evaluation in hallux valgus surgery

Introduction: WBCT has been recently being introduced as a powerful tool, but little has been published about pre and post op hallux valgus surgery changes

Objetive: Compare pre op classic mesurements in xrays and WBCT

Méthods Different hallux valgus angles were mesured including: hallux valgus (HVA)angle, Intermetatarsal angle (IMTA) and distal articular angla (DMAA), in xrays and WBCT by 3 different observers. Correlation was performed between both methods . Spearman correlation and interclass Correlation coeficient were evaluated between both mesurements.

Results: 18 feet with hallux valgus were evaluated. Average age was 39,7 años. 72,2% were female. AP x rays the average angles were HVA 23,5, IMTT 14 and DMAA 11. In WBCT they were 24,5, 14 y 12,5 respectivly. The Spearman correlation coeficient was 0,813 para HVA, 0,878 for IMTT and 0,715 para DMAA. The interclass correlation coefficient was 0,973 for HVA, 0,910 for IMTT and 0,874 for DMAA

Conclusion: These 3 angles had excellent correlation between weight bearing xrays and WBCT. Interclass correlation in between interobservers was also good. So, both methods would be appropiate to measure HVA, IMTA and DMAA

A different scenario was observed when rotation was analized. Rotation has recently been mentioned like and important recurrent factor in hallux valgus analysis. Most authors have indirectly measured the deformity (xrays, simulated weight bearing CT). We are not aware of any study measuring rotation before and after scarf osteotomy. And this is the preliminary study while the post op mesurements are being performed.

Objetive: Correlate first metatarsal head morphology and sesamoid position in weight bearing x rays with pronation and sesamoid position measured in WBCT.

Methods: Shape of the first metatarsal was evaluated in order to messure rotation d(Round Sign) and sesamoid position under the metatarsal head was classified. Thew alfa angle wes separated iun 4 stages (0 = 0 to 10° ; 1 = 10 to 20° ; 2 = 20 to 30°: and 3 = or more than 30°). Using WBCT sesamoid position under the metatarsal head was also mesured Kappa indez was used to compared both methods.

Results: AP WB xrasy 44,4% had alpha angle type 1, 50% type 2 and 5,6% type 3. In WBCT 27,8% had pronation type 0, 61,1% typo 1, 11,1% type 2 y 0% type 3. Kappa index was -0,073. Under xrays sesamoid position was type 1 in 0%, type 2 in 50%, type 3 in 38,9% and typo 4 in 11,1%. In WBC it was type 1 en un 33,3%, type 2 in 55,6%, type 3 en un 11,1% and type 4 en un 0%. Kappa index = 0,061.

Conclusion: Correlation between pronation and sesamoid position under the metartarsal head was poor in both methods. Since there is significant differences between xrays and WBCT we recommend to use exclusively WBCT to evaluate rotation of the firs metatarsal for surgical plan.

Identification of the biomechanical risk due to the use of industrial footwear in workers with prolonged bipedal postures

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Prolonged bipedal posture is one of the leading causes of musculoskeletal disorders and neuropathies of the lower extremities due to the high requirement for metabolic output and restricted blood circulation compared to sitting position [1,2].

Objective:
Identify the biomechanical risk generated by the use of industrial footwear in workers with maintained and prolonged bipedal postures through the occupational ergonomic diagnosis of the activities carried out by employees and their subsequent biomechanical analysis with IMU technology (Inertial Measurement Unit).

Materials and methods:
Within the design of the experiment, two measurements are established for the quantification of biomechanical risk through inertial units of movement, in which the human gait with which the worker develops in his working day is analyzed. The first, at the beginning of the day. The second at the end of it, according to the rules implemented by each company 3 workstations are analyzed (Table 1) where safety footwear is used and the biomechanical analysis is carried out from the IMU.

Results:
According to the analysis and data capture, the tests of the 3 subjects evaluated present altered results when comparing the gait curves with each other both at the beginning of the working day and at the end of the same (Figure 1). Which can be associated with the generation of different pathologies of the lower extremities; mainly biomechanical pathologies.

Table 1. Study group demographics.

Workstation	Gender	Age (years)	Height (m)	Weght (kg)	BMI(kg/m2)
Storer	Male	24	1.68	65	23.03
Supervisor	Male	55	1.58	71	28.44
Maintenance	Male	58	1.67	80	28.7

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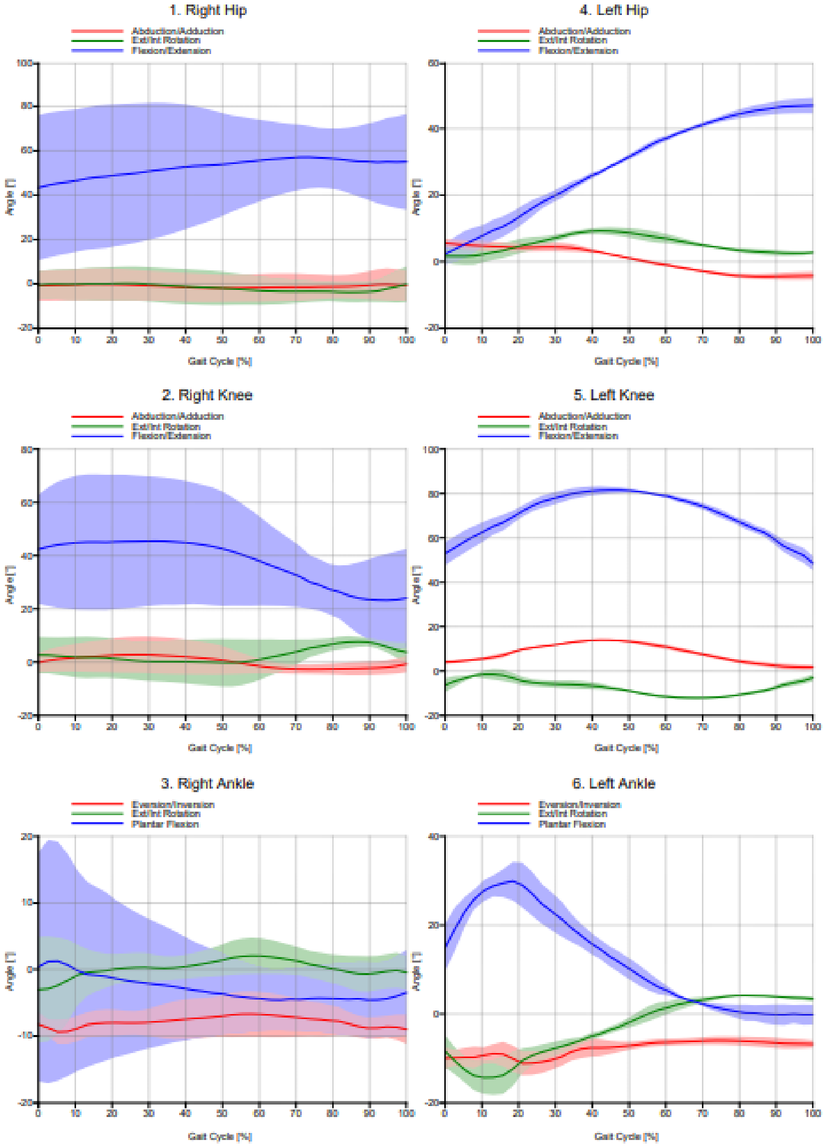
Figure 1. Biomechanics analisys gait in workstations.



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Implant fixation influences tibial bone strain after total ankle replacement: A Finite Element Study

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INTRODUCTION: Total ankle replacement (TAR) is a surgical intervention for end stage OA of the ankle. Clinical outcomes are less positive than other joint replacements, with mechanisms for failure poorly understood. Retrieval analysis of failed implants has shown differing levels of bone-implant integration and hence fixation of TAR. High strain within bone is associated with microfracture and alters the bone-implant interface. The aim of this study is to explore the influence of implant fixation on tibial bone strain using patient specific finite element models.

METHODS: Five cadaveric ankle joints were CT scanned (82um, Scanco Xtreme) before being segmented (Simpleware ScanIP) into individual bones and virtually implanted with a stemmed mobile-bearing TAR according to published surgical technique. Patient specific finite element models were created and run with axial load corresponding to peak load from literature [1]. Sliding contact between implant surfaces was applied, with the inferior talus fixed at the subtalar joint surface. All components were meshed with linear tetrahedral elements, with bone material properties derived from CT greyscale data. Fixation levels of the tibial component were altered, from fully fixed (Representing full bone ingrowth) to frictionless (Representing no bony fixation). Bone strain distributions around the implant were measured.

RESULTS: Clear differences in strain were found between different ankle specimens and fixation type, with highest strains occurring during frictionless fixation at the tip of the tibial component (Fig. 1). At the tip, average maximum principal strain increased from 0.16% to 0.42%. Higher strains were seen in subjects with poorer bone quality, with increased malleolar strains in some subjects, indicative of the potential for malleolar fracture [2].

DISCUSSION: In all specimens, strain around the implant was higher in cases simulating no bony fixation, highlighting that fixation may be a critical factor in TAR failure. These results support clinical findings that failure is more likely to occur if fixation of the implant is low, such as those seen in cases of ballooning osteolysis [3]. Good bone quality is thought to be an important factor in the success of TAR, with increased malleolar strains found in patients with predominantly poorer bone quality. Differences observed across specimens highlight that TAR may not be a suitable intervention for all patients due to variation in bone quality and anatomy.

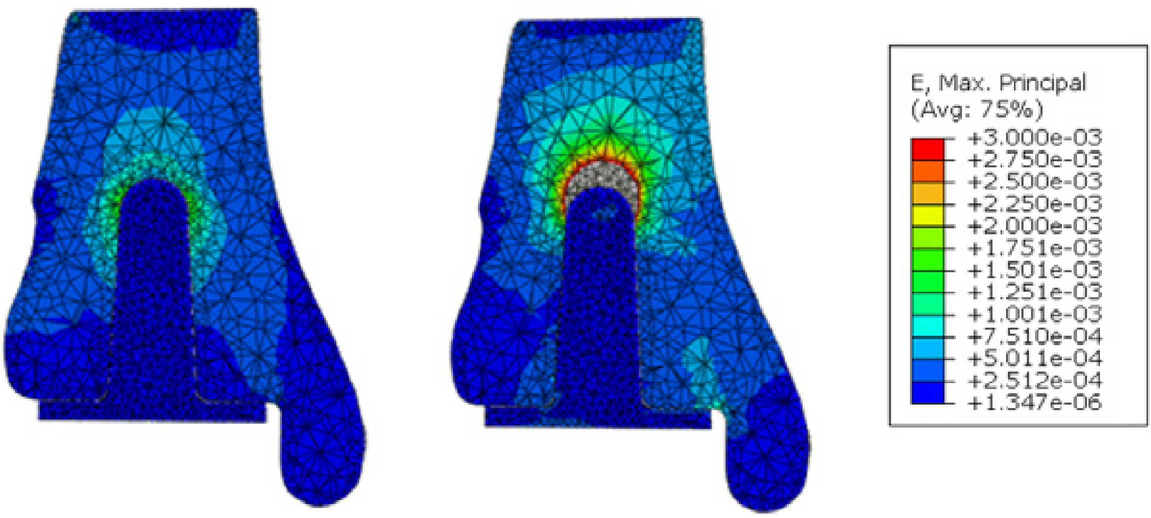

Figure 1. Output of the tibial component for fixed and frictionless cases showing increase in tensile strain at the implant tip and elevated malleolar strains.

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Importance of measuring foot intrinsic and extrinsic muscle forces in diabetic subjects

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Introduction

Intrinsic foot muscle weakness has been implicated in a range of foot deformities and disorders [1]. Atrophy of the intrinsic muscles has been associated to diabetic neuropathy (DN) and thus both muscle strength and motor function in the feet of the neuropathic subjects are severely compromised [2]. However, to establish a relationship between intrinsic muscle weakness and foot pathology, an objective measure of intrinsic muscle strength is needed [1].
The aim of this work is to develop a methodology to quantitatively assess the degree of weakness of intrinsic and extrinsic foot muscles in diabetic subjects. This methodology could be used to analyze implications of intrinsic and extrinsic muscle weakness in diabetic foot pathology and determine the effect of foot strengthening interventions [3].

Methods

Ten subjects (7 healthy (HS): age 48.1±15.22 years, BMI 21.9±1.4 kg/m^2, 5 diabetic neuropathic subjects (DNS): age 58.40±7.76 years, BMI 25.93±2.67 kg/m^2) were analyzed. A stereophotogrammetric system (BTS) synchronized with 2 pressure plates (Imagortesi), 2 force plates (Bertec), and a 16 channels surface electromyographic system (BTS) were used for gait analysis, adopting a 3D multi-segment foot markerset with a full body one for kinematics [4]. In term of musculoskeletal modelling, a 6DOF foot model with intrinsic foot muscles was adopted [5]. The extrinsic muscle activations were validated against experimental surface electromyography [3]. Evaluation was focused on the stance phase of gait. Kruskal-Wallis test ($p<0.05$) was used for comparing results between the two cohorts of subjects.

Results

Statistically significant differences were registered between DNS and HS foot muscle forces associated to altered foot and ankle kinematics, and both ground reaction forces and joints moments. An increased dorsiflexion angle was found at the loading response and push-off phases of gait associated to excessive ground reaction forces and reduced ankle plantar-dorsiflexion moment. A reduced Peroneus Brevis force was measured over the whole stance phase of gait accompanied by a reduced Tibialis Anterior force at midstance and pushoff, while excessive forces were registered at Gastrocnemius Medialis and Flexor Hallucis Brevis compressively, and Tibialis Anterior only at loading response (Fig. 3).

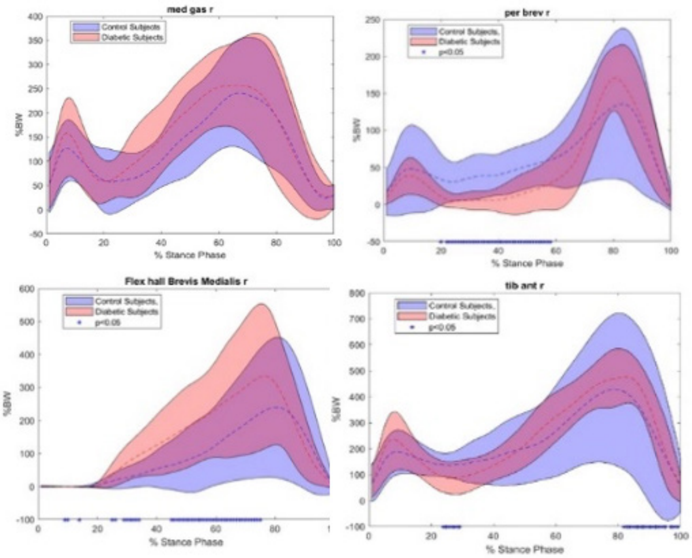

Figure 3: From the top left, Gastrocnemius medialis, Peroneus Previs, Flexor Hallucis Brevis and Tibialis Anterior muscle forces

Conclusion

Results of the present study, even though preliminary, seem to indicate an imbalance of the flexor and extensor foot muscle forces during gait in DNS. This methodology could be used for planning specific selective foot muscles strengthening protocols, and assessing the effect of the interventions.

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In vivo changes in distal interosseous tibiofibular ligament elongation under static loads and during dynamic activities after syndesmosis repair

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TRODUCTION: Injuries to the ankle syndesmosis have frequent indication for operative repair[1]. Although cadaver studies can evaluate syndesmosis fixation strength, they cannot predict how healing, neuromuscular adaptation, or dynamic loading will affect *in vivo* biomechanics. Using dynamic biplane radiography (DBR), we tested the hypothesis that syndesmosis repair would restore ankle kinematics and ligament elongation during static and dynamic loading.

METHODS: Six males were imaged 2 to 4.7 years after surgery at 150 images per second using DBR (2 screw fixation, 3 tightrope, 1 hybrid) during forward running, backpedaling, a 45° angled single-leg hop, and one static standing trial. Three-dimensional ankle kinematics and elongation of the interosseous ligament (IOL) were measured bilaterally using a validated tracking system that matched patient-specific 3D bone models obtained from CT to each pair of synchronized biplane radiographs with an accuracy of 1.1 mm in translation and 2.8° or better in rotation[2]. The IOL was represented by 10 discretized segments spanning the gap between the distal tibia and fibula (Figure 1). Ligament lengths and tibiotalar kinematics were measured in the static unloaded condition from CT scan, in the static loaded condition from standing biplane radiographs, and during dynamic activities from tracked bone kinematics in dynamic biplane radiographs. Clinical outcomes were evaluated using the Foot and Ankle Ability Measure (FAAM). Paired t-tests were used to identify differences between repaired and healthy ankles.

RESULTS: Static load increased the lengths of the distal IOL ($p = 0.02$ to 0.05) (Figure 2) only on the repaired ankle. The distal syndesmosis length was greater on the repaired side during the static unloaded and loaded conditions ($p = 0.01$ to $p = 0.02$) (Figure 2). Length of the distal syndesmosis on the repaired side was greater than the corresponding healthy syndesmosis length during all three dynamic activities (Figure 3). On average, the repaired ankle was in less dorsiflexion (or more plantarflexion) over the support phase of the angled hop ($p = 0.05$) and running ($p < 0.01$) (Figure 4). The average FAAM-ADL and Sports subscale scores were 95 and 88, respectively.

DISCUSSION: This study provides the first *in vivo* biomechanical evidence identifying post-fixation changes that may contribute to long-term outcomes after syndesmosis repair. Syndesmosis repair fails to restore healthy static and dynamic distal tibiofibular anatomy, even in patients who report good to excellent clinical outcomes.

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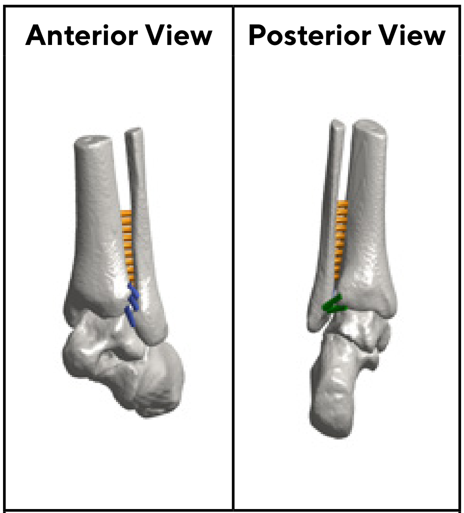

Figure 1. A representative 3D model of the ankle and hindfoot bones including the syndesmosis (orange), AITFL (3 purple elements) and PITFL (2 green elements) ligaments. The syndesmosis was modeled using 10 discrete components, from Syndes 1 (most distal, starting 10 mm from the tibiotalar articulating surface) to Syndes 10 (most proximal). Changes in ligament length were calculated based upon the bone kinematics measured using biplane radiography.

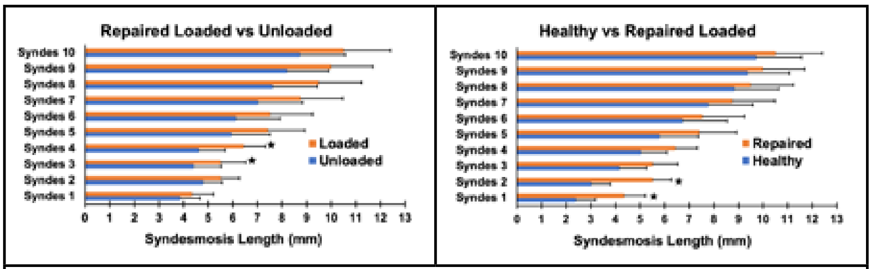

Figure 2: The effects of load on the repaired syndesmosis lengths (left) and healthy versus repaired syndesmosis lengths while loaded (right). Unloaded (during supine CT scan) and loaded (during standing biplane radiography). Error bars represent 1 standard deviation. Stars indicate significant differences at p < 0.05.

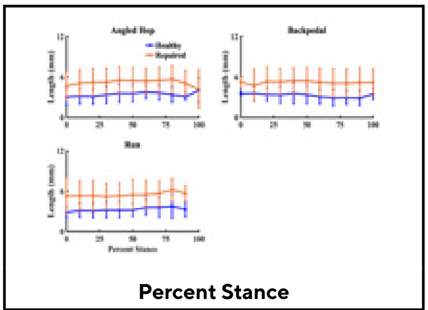

Figure 3: Average dynamic syndesmosis length in the distal syndesmosis (Syndes 2) in the healthy (blue) and repaired (orange) sides during angled hop. Error bars represent 1 standard deviation.

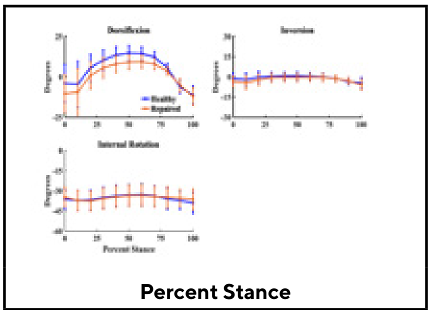

Figure 4: Average tibiotalar dorsiflexion during the angled hop activity for the healthy side (blue) and repaired side (orange). Similar results were observed for the backpedaling and running activities.

Increased jerk during a single-limb jump-stabilization task is associated with worse symptoms of ankle joint health among individuals with chronic ankle instability.

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Introduction: Early biomarkers of articular cartilage breakdown associated with chronic ankle instability (CAI) are likely due to aberrant movement patterns and altered loading of the talocrural joint, causing symptomatic post-traumatic osteoarthritis (PTOA) [1,2]. Jerk is a novel measure to examine abnormal movement patterns seen in those with CAI. Jerk quantifies the relative smoothness of a dynamic task as a person achieves and maintains balance [3]. More frequent postural control corrections may increase shear forces on articular cartilage, contributing to increased symptoms of ankle PTOA. Thus, the purpose of this study was to compare the resultant vector jerk during a single-limb (SL) jump-stabilization task and symptoms of ankle PTOA between individuals with and without CAI. The secondary purpose was to examine the association between jerk and symptoms of ankle PTOA among those with CAI. **Methods:** Twenty participants with CAI (age: 23.0±3.5 years; height: 168.1±9.6 cm; mass: 70.8±13.6 kg) and 19 un-injured control participants (age: 24.3±2.6 years; height: 168.5±6.8 cm; mass: 64.9±10.5 kg) volunteered for this case-control study. Participants completed the Pain and Disability subscales of the Ankle Osteoarthritis Scale (AOS). Next, participants completed a jump-stabilization task requiring them to jump from two feet, touch a marker 50% of their maximal vertical jump height, then land and maintain SL stance for three seconds. Kinetic data were collected at 1000 Hz using an embedded Bertec force plate, filtered with a low-pass fourth-order Butterworth Filter at a frequency of 12 Hz. Jerk was calculated as the third derivative of the ground reaction force resultant vector. Separate Independent T-tests and Mann-Whitney U tests were used to compare jerk and scores on the AOS between groups, respectively. Spearman rank correlation coefficients were used to assess the relationship between jerk and AOS subscale scores within the CAI group. **Results:** Participants with CAI had increased jerk and higher scores on both AOS subscales (Table 1). A positive correlation was observed between jerk and the AOS Pain (ɑ0.354, p=0.023) and Disability (ɑ0.433, p=0.005) subscales. **Discussion:** Increased jerk among those with CAI indicates the need to make more postural adjustments to balance after landing from a jump. The increased scores on both AOS subscales suggests individuals with CAI self-report more clinical symptoms of PTOA. **Relevance**: The relationship between jerk and the AOS provides support to models that theorize biomechanical alterations alter loading patterns imposed on articular cartilage of the talocurual joint, contributing to increased symptoms of worsened joint health.

Table 1. Group means ± standard deviations for all primary outcome measures.

	CAI (n = 20)	Un-injured Controls (n = 19)	p-value
Jerk (cm/sec^3)	8511.2 ± 2868.8	6706.6 ± 2346.7	p = 0.039
Ankle Osteoarthritis Scale			
Pain (%)	12.4 ± 15.2	0.0 ± 0.0	p < 0.001
Disability (%)	14.1 ± 15.0	0.0 ± 0.0	p < 0.001

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Individual differences in intrinsic ankle stiffness: their relationship to body sway and ankle torque

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Introduction

While controlling unstable quiet standing, the central nervous system actively modulates joint torque, supplementing torque provided by intrinsic stiffness. Previous research has shown that standing intrinsic ankle stiffness has a general tendency to increase with ankle torque and decrease with ankle movement, amid a large range across different individuals [1–3]. We might expect that people with intrinsically stiffer ankles would sway less when standing. However, the effect of intrinsic ankle stiffness on body motion when standing on a moving surface, or how it is influenced by ankle torque, is unknown. Here we study the relationship between intrinsic ankle stiffness, torque and movement, measured in both static and moving support surface conditions.

Methods

Intrinsic ankle stiffness of 19 freely standing participants was estimated by recording ankle angle and torque responses to brief (140 ms) and small 0.1 and 0.7 deg perturbations, measuring short- and long-range intrinsic ankle stiffness, respectively. During separate trials, participants either stood quietly on a fixed platform or stood on the same platform when it was being moved by very slow sinusoidal tilts (0.2 & 0.4 deg amplitude at 0.1 Hz). Body movement was separated into the spontaneous sway component (natural random relatively rapid postural adjustments occurring during standing, measured as RMS body velocity, a measure of instability), and the evoked tilt component (much slower synchronous evoked tilt induced by the sinusoidal movement of the platform, measured as peak-to-peak body displacement amplitude).

Results

The results show the anticipated inverse correlation between intrinsic ankle stiffness and spontaneous sway, being true only when correlating with *short*-range ankle stiffness, and unrelated to ankle torque. In contrast, long-range ankle stiffness was unrelated to spontaneous sway, but had a positive correlation with ankle torque. Furthermore, the magnitude of evoked tilt did not correlate with either short- or long-range intrinsic ankle stiffness.

Discussion and Relevance

Our novel finding is that the relationship of torque and movement to intrinsic stiffness depends on the size of the measuring perturbation, i.e., individuals with greater short-range stiffness tend to sway least. When the support surface was slowly rhythmically tilted, individuals tilted in synchrony with the surface, but their response to tilting was uncorrelated to short- or long-range intrinsic stiffness. The implication is that the mechanisms related to short term stabilisation are different from the process of defending a particular body position. Intrinsic ankle stiffness is useful for the former process but does not affect the latter.

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Influence of foot orthotics on fifth metatarsal strains during simulated gait

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INTRODUCTION: Fractures of the fifth metatarsal account for a high proportion of lower extremity fractures in young, athletic population. Sub-optimal outcomes are frequently reported during conservative treatment of this injury [1]. Surgical fixation minimizes the risk of suboptimal outcomes, however, reinjury remains a clinical concern. Thus, the development of intervention strategies to mitigate the risk of initial fracture is important. Foot orthotics have been used as an intervention strategy to prevent lower extremity fractures [1]; however, few studies have examined their effect on mitigating fifth metatarsal injury. Therefore, the aim of this study was to investigate the use of semi-custom orthotics throughout cadaveric gait simulation.

METHODS: Seven cadaveric foot specimens were loaded to simulate the stance of normal gait using a validated, 6-degree of freedom robot with tendon actuators [2]. Strain gauges were placed at the metaphyseal-diaphyseal junction (Zone II), and the proximal diaphysis (Zone III) of the fifth metatarsal to measure principal strain throughout stance. Specimens were tested in sneakers for thirteen orthotic conditions which include combinations of a commercial orthotic insole, three plates, and two foam wedges. A repeated measures ANOVA with a Bonferroni correction was conducted to compare orthotic conditions to the sneaker condition.

RESULTS: No statistically significant differences were present between the sneaker and orthotic conditions. Six specimens demonstrated reduced Zone II and Zone III strains during orthotic conditions (Figure 1). Zone II microstrain was most consistently reduced in orthotic conditions that include a lateral plate with a wedge placed at the base of the fifth metatarsal. Zone III microstrains maintained a relatively consistent level of percent change across orthotic conditions.

DISCUSSION: The results from this study indicate that peak microstrain in Zone II and Zone III could be reduced by foot orthotics relative to the sneaker condition. Zone II microstrains were consistently reduced in conditions in which lateral plates and wedges were present, thus Zone II strains could be decreased through orthotics which are designed to redistribute loads to the medial aspect of the foot. Zone III microstrain maintained a relatively consistent percent of change in microstrain and had a greater variation between specimens. It is possible the intra-specimen variance observed in Zone III could be explained by morphological differences, which have previously been correlated to increased risk of fifth metatarsal fracture [3]. The results from this study provide insight into the development of intervention strategies that could reduce fifth metatarsal fracture risk.

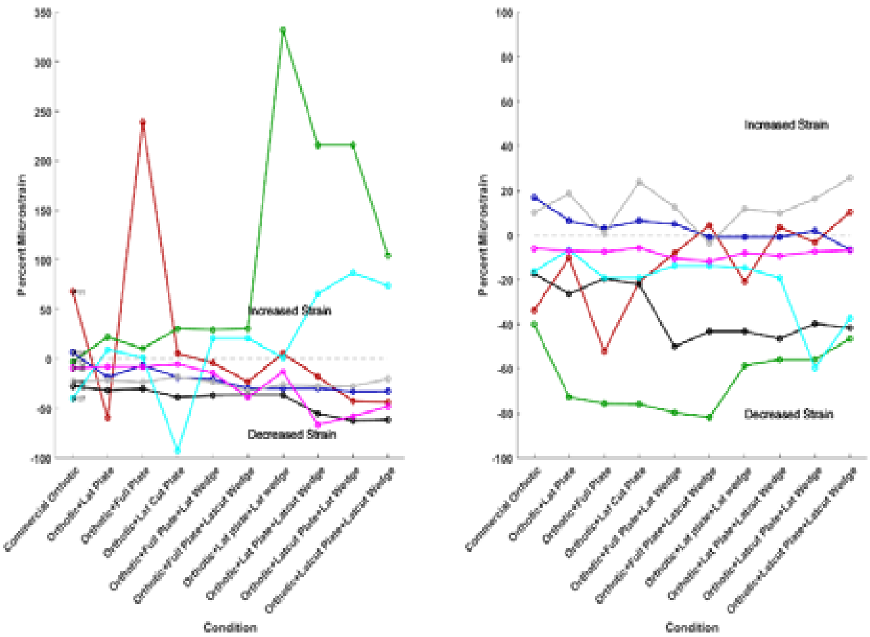

Figure 1: Percentage change in microstrain in Zone II and Zone III during orthotic conditions compared to the sneak alone

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Investigation of Human Foot Function Using Approaches in Imaging and Musculoskeletal Modeling

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The human foot is unique among living and extinct non-human primates. Obligate bipedalism, facilitated partly by changes in foot structure and function, is considered one of the great transformations in human evolution. The way the foot deforms at contact and recoils during push-off is presumed to be unique and the result of alterations in bone shapes, the adducted great toe, as well as the presence of a substantial aponeurosis and a medial longitudinal arch. These structures are different, reduced, or absent in other extant apes and are theorized to be evolutionary adaptations that are the result of selective pressures for habitual walking and running economy. Ideas around the requirements of efficient bipedalism and how the foot has adapted to these requirements have shaped conceptions about what makes us human and subsequently influenced approaches to treat foot pathologies, as well as prosthetic, orthotic, and shoe design.

The foot helps maintain balance, absorb shock and assists in push-off during locomotor activities. There are many theories about how and why the foot has evolved the way it has and how it functions, yet very few of the proposed form-function relationships have been tested well enough to be accepted or refuted. The purpose of this talk is to discuss our research investigating foot form and function with new approaches using state-of-the-art approaches in imaging and biomechanical modeling. These approaches may allow us to revise our understanding of how the foot contributes to bipedal locomotion.
There are three proposed mechanisms which are thought to provide humans with an advantage for efficient bipedal locomotion across various substrates. The first is the arch-spring model that describes use of elastic tissues, such as tendons and ligaments, to create a spring-like foot that is capable of first absorbing energy and then returning this energy through deformation and recoil of the medial longitudinal arch. This theory is consistent with evidence of other mechanisms that take advantage of elastic storage in humans and other organisms. The second is known as the windlass mechanism. The windlass is facilitated by the plantar aponeurosis – a thick band of ligamentous tissue that inserts at the calcaneus (heel bone) and spans the bottom of the foot, wrapping around the metatarsal bones and inserting on the toes.

In 1954, Hicks proposed that the plantar aponeurosis essentially functions as a rigid cable, winding the aponeurosis around the metatarsal heads as the toes extend, which shortens and stiffens the arch. Finally, the human mid-foot is thought to be stiffer than most other primate species (both quadrupedal and bipedal), which reduces mid-foot break and creates a more rigid lever for force production. Mid-foot stiffness is thought to be facilitated by the transverse tarsal locking mechanism, where the axes of rotation of bones in the mid-foot move from an aligned position facilitating mobility, to a crossed orientation, effectively stiffening the foot. Recently, all three mechanisms have been questioned. Finally, other important features, such as the transverse arch have been identified as important to foot function. It is our position that a unified framework is needed to understand how the foot mechanically functions. The goal of this proposal is to establish this framework.

Investigation of muscle strength, motor coordination and balance in children with idiopathic toe walking: analytical cross-sectional study

Introduction: Gait pattern in children with idiopathic toe walking (ITW) is characterized by premature activation of calf muscle and superposition of its activity over anterior tibialis (AT). Moreover, the morphological pattern of the triceps surae (TS) is characterized by a predominance of type I fibers which could lead to a reduced strength of these muscles. Although there are studies evaluating the morphological pattern of the TS and its relationship with a possible weakness, there are no studies comparing the strength of the TS and AT of children with ITW and healthy children.

Objective: To compare the muscle strength, ankle dorsiflexion range of motion (ROM), balance and motor coordination of children with ITW with healthy children.

Methods: Thirty children were recruited; fifteen children aged between 5 and 11 years, of both sexes, with a history of ITW and fifteen healthy (control) children, matched for age, weight and height to ITW cases. Ankle dorsiflexion ROM was assessed through the lunge test with a goniometer. TS and AT muscle strength was assessed through isometric hand-held dynamometry. Motor coordination and balance were assessed through KTK test. Differences between ITW cases and healthy control children were assessed using Student T-Tests and Mann-Whitney U Test.

Results: Children with ITW presented with reduced TS strength (mean difference (MD): 23.2 Kgf; effect size (ES): 1.02; $p<0.05$), reduced AT strength (MD: 8.6 Kgf; ES: 1.09; $p<0.05$), reduced ankle dorsiflexion ROM (MD: 20°; ES: 2.99; $p<0.001$), and impaired motor coordination and balance (MD: 18.6 points; ES: 1.41; $p<0.001$) compared to healthy children.

Conclusion: Children with ITW have reduced TS and AT muscle strength, reduced ankle ROM and impaired motor coordination and balance when compared to healthy children.

Relevance: This study has elucidated important deficits in children with ITW, these results are important to guide the rehabilitation of these children.

Key Words: Idiopathic Toe Walking, motor coordination, balance, muscle strength

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Is first ray hypermobility related to the flat foot?

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First ray hypermobility is a condition which has been linked to initiation of First Metatarsophalangeal (MTP) joint Osteoarthritis (OA). Individuals with a planus foot type exhibit a higher-odds ratio of this disease (Menz et al., 2015). First ray hypermobility has anecdotally been associated with pes planus; however, the relationship between these conditions is unclear. Therefore, this study examined the first ray mobility of subjects with pes planus and pes rectus to determine whether an association exists between foot type and first ray hypermobility.

The study included 6 rectus subjects (N=12 feet) and 10 planus subjects (N=20 feet), who were asymptomatic, for a total of 16 participants (N = 32 feet). Each subject was categorised according to their foot type based on measurements with the Arch Height Index (AHI) system which has been previously described (Hillstrom et al, 2013). Arch Height Flexibility (AHF) of each subject (change in deformation of the medial arch from partial weightbearing to full weightbearing) was computed. The maximum dorsiflexion capability of each first MTP joint was also recorded with a test-rig previously shown to be reliable. A novel device was used to measure first ray mobility of each subject with their foot in Resting Calcaneal Stance Position (RCSP) while seated. The first ray mobility was subsequently normalised to foot length to provide a First Ray Mobility Index (FRMI):

$$\text{FRMI} = \frac{\text{Dorsal First Metatarsal Height}_{50N} - \text{Dorsal First Metatarsal Height}_{0N}}{\text{TFL}} \qquad (1)$$

The AHF, maximum first MTP joint dorsiflexion, and FRMI were not significantly related to foot type. The raw measurements of first ray mobility demonstrated a significant difference between the planus and rectus foot types. On average, subjects with pes planus exhibited greater first ray mobility than those with pes rectus (Table 1).

While this study demonstrated a significant relationship between pes planus and first ray mobility, it must be considered that a small sample size was used. In future research, a larger cohort will be performed to improve statistical power and hence, any observed associations. Nevertheless, this study represents a novel insight into the interaction between first ray mobility and foot type. Hypermobility of the first MTP joint and the planus foot type may be risk factors for hallux rigidus or OA in the long-term but additional research is required to prove this assertion with longitudinal data.

Table 1. Foot type characteristics: planus versus rectus.

Foot type characteristics	Planus		Rectus		GEE Results	
	Mean	SD	Mean	SD	X^2	*p*-value
$AHI_{standing}$	0.317	0.004	0.357	0.003	53.00	**0.000***
AHF (mm/kN)	18.05	1.62	15.08	2.24	1.15	0.283
Maximum dorsiflexion (°)	75.9	2.7	81.9	5.5	0.92	0.338
First ray mobility (mm)	9.30	0.66	7.46	0.62	4.13	**0.042***
FRMI	0.498	0.047	0.398	0.037	2.81	0.094

Statistical significance <0.05 is indicated by bold text and an *.

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Isolated gastrocnemius tightness: impact on foot diseases

Backgroud: The objective of this study was to evaluate the difference in muscle strength between flexion and ankle extension to test the hypothesis that this predisposes to a dynamic equine, and thus to evaluate this correlation with pain in the forefoot (metatarsalgias) and hindfoot (plantar fasciitis, tendinopathy of the tendon insertional and non-insertional calcaneus).

Methods: In this prospective cohort study 50 patients were consecutively diagnosed with forefoot pain (metatarsalgias) or pain in the hindfoot (plantar fasciitis, tendonopathy of the insertional and non-insertional calcaneal tendon) and 50 patients without foot diseases. The body mass index (BMI) was evaluated and the IGT was evaluated through the Silfverskiöld test. The parameter of gastrocnemius contracture was considered in cases of limitation of ankle extension <10. The intervention was to measure flexion strength and ankle extension with a manual dynamometer, evaluating isometric contraction based on the method suggested by Kahn et al.

Results: One hundred patients participated in the study, being 50 patients in the study group and 50 in the control group. The mean age was 63.42 years and the mean BMI was 28.53 in the study group and 62.26 and the mean BMI was 28.84 in the control group, with no difference in the distribution between age groups ($p = 0.634$) and for BMI ($p = 0.709$). The difference between the groups in relation to the Silfverskiöld test ($p = 0.019$), the ankle force variation in dynamometry ($p < 0.001$) and normalized variation ($p < 0.001$). In addition, the groups presented a statistical difference in the dynamometry of the plantar flexion ($p < 0.001$).

Conclusion: We have demonstrated the possibility of the evaluation of the force through a manual dynamometer that can be used in routine outpatient visits since the method proved to be effective, and in addition because of its reproducibility.

LEVEL OF EVIDENCE: Level I: High-quality prospective randomized clinical trial

Key-Words: Isolated gastrocnemius tightness, Achilles tendon; Ankle Joint; Mobility limitation; Foot diseases, manual dynamometer, biomechanics

Long-term effects of medial-wedged insoles in over-pronated feet on the lower limb kinematics during walking: preliminary results

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Orthopedic insoles are often prescribed to control excessive foot pronation during gait [1]. However, there is a little scientific evidence on the long-term effects of these orthoses. Therefore, the objective was to investigate whether the short-term effects of medial-edged insoles with medial longitudinal arch support on gait kinematics of individuals with excessive foot pronation persist in the long-term. Ten females and nine males volunteers (27±8 years, 21.6±2.93 kg/m^2 and Foot Posture Index between +6 and +12) walked five times at self-speed along a 10 meters walkway wearing intervention insoles (Figure 1) and five times wearing control insoles (flat EVA), both inside of neutral running shoes (New Fit, Bout's, Brazil). The kinematic data were captured at 200Hz by an optoelectronic system (nine cameras Oqus 3+, Qualisys, Sweden). The subjects wore intervention insoles for three months and data were collected at three moments: initial assessment (M1); after 6 weeks (M2) and after 12 weeks (M3). Kinematic data were analyzed on Visual3D (V6, C-Motion Inc., USA) filtered by a Butterworth filter (4th order and cutoff of 6Hz) and time-normalized to 101 points within one gait cycle. The calculated kinematic variables were hip and knee medial rotation peak and calcaneal eversion peak. Data were compared in SPSS (v.22, SPSS Inc., EUA) using a two-way ANOVA considering an alpha level of ≤ .05. The results are shown in Table 1. As in studies that evaluated the short-term effects of orthopedic insoles, this study also observed a reduction in calcaneal eversion peak and internal knee rotation peak in M1 [2,3]. The effect of the intervention insole on hip internal rotation began only in M2 and remaining in M3 suggesting a possible long-term tissue adaptation, and their effect on the knee transverse plane is no longer significant in M3 with greater transmission of torsional movement to the hip. The results of the present study suggest that the short-term effect of medial-wedged insoles applied to over-pronated individuals changes over time in the knee and hip joints, remaining unchanged in the feet.

Table 1. Comparison table

		CIp - IIp	p-value	Effect size
Hip internal rotation peak (degrees)	M1	0.677	0.066	0.346
	M2	0.727	0.021*	0.288
	M3	0.857	0.002*	0.236
Knee internal rotation peak (degrees)	M1	-0.870	0.035*	0.382
	M2	-0.846	0.005*	0.262
	M3	-0.665	0.352	0.696
Calcaneal eversion peak (degrees)	M1	-1.948	< 0.001*	0.366
	M2	-2.124	< 0.001*	0.326
	M3	-1.341	< 0.001*	0.312

CIp = control insole peak average; IIp = intervention insole peak average; M1 = initial assessment; M2 = after 6 weeks; M3 = after 12 weeks; *statistically significant results.

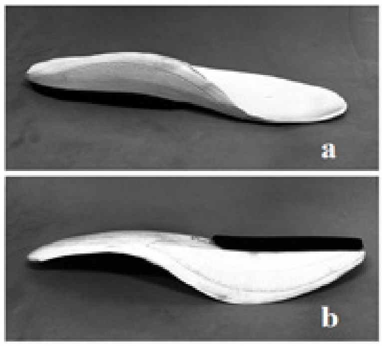

Figure 1. Intervention insoles produced in EVA with a) a medial longitudinal arch support and b) a 6° medial wedge.

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Longitudinal aspects of foot sensitivity in normal aging and mild cognitive impairment (MCI)

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Background

Aging is the accumulation of deleterious changes in tissues that increase the risk of disease [1]. Cutaneous sensitivity deteriorates with advancing age [2]. However, there is a lack of information about longitudinal aspects of sensitivity deterioration, especially when cognitive changes are already present, for example in subjective cognitive impairment (SCI) and mild cognitive impairment (MCI).

Methods

Thirty-six subjects (13 MCI; 8 SCI and 15 healthy controls (CG); mean±SD: 82.1±2.2 yrs) participated in this study. Data were collected twice (T1 and T2), with an interval of 8-9 months between them. The Montreal Cognitive Assessment (MoCA) and a questionnaire for complaints of cognitive disturbances (FLei) were used to determine the groups. Three trials of vibration perception thresholds (VPTs) at 30Hz were collected at the foot (Met I). Means of the VPTs were used for statistical analyses.

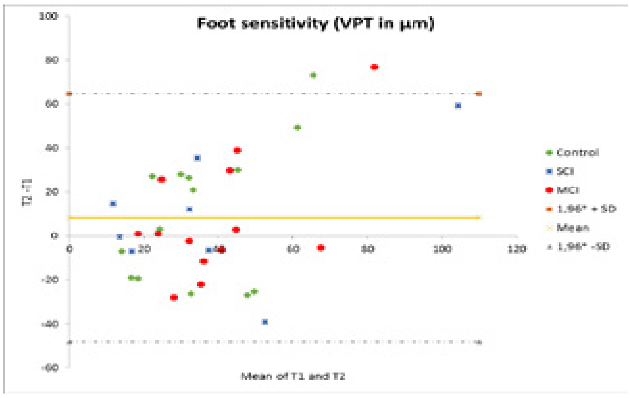
Results

Higher but non-significant VPTs were found for MCI and SCI (cross-sectional), and in T2 for all groups (longitudinal) (Table 1). Figure 1 shows a difference plot comparing T1 and T2 for all groups.

Table 1. Mean±SD sensitivity (VTP, in µm) at foot for CG and MCI.

	CG	SCI	MCI
T1	29.5±15.8	33.5±26.7	36.2±15.2
T2	38.0±27.8	42.1±39.5	44.0±28.3

Figure 1. Bland and Altman plot of VPTs for all groups and T1 and T2. Y-Positive values represent decreases in sensitivity.



Conclusions

Aging affects sensitivity [2], but our data cannot confirm this after a period of 8-9 months. Note that our data exhibited a large heterogeneity. However, clinically relevant differences (based on RMSE calculations) indicate that the majority of subjects from all groups exhibited relevant deteriorations of VPTs at T2. Furthermore, there seems to be a trend toward poorer skin sensitivity for MCI and SCI compared to CG. This is plausible, since anatomical structures related to sensitivity inputs are already negatively affected in MCI [3]. Further measurements are planned to provide insights into the brevity of sensitivity decline and information-processing structures in MCI and SCI.

Trial registration

Clinical trials register number DRKS00013167

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Longitudinal plantar arch stiffness during running by different arch definitions

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Background: The medial longitudinal plantar arch (MLA) is the foot feature that is most investigated in biomechanical literature due to its relationships to function and diseases. MLA acts as a spring that stores and restores energy during its deformation, and acts as a dampener, attenuating forces[1]. In this context, an interesting variable to measure MLA properties would be its stiffness. This can be measured dynamically and it is accurate enough to respond to foot muscles activity and passive structures alterations [2]. However, stiffness values are affected by the kinematic model of MLA used in the analysis. Our aim was to investigate the agreement between MLA quasi-stiffness proposed by the Farris et al. (2019) [2] using different skin-markers based models of MLA . Clinicaltrials.gov Identifier NCT02306148

Methods: The foot kinematics of 55 healthy recreational runners were measured using 8 infrared cameras (Vicon Vero) while running barefoot on an instrumented treadmill (AMTI) at self-selected speed. Sixteen reflective markers were placed on subjects' anatomical references according to the Rizzoli Foot Model (RFM). Quasi-stiffness was calculated as the average slope of 10 trials' moment-angle curves [2]. The stiffness was analyzed in two phases: (i) ankle flexion phase and (ii) ankle extension phase. Bland-Altman plots were used to analyze MLA stiffness calculated using the sagittal Cal_Met angle, as defined by Farris et al. [2], and four other skin-markers based MLA definitions described elsewhere [3]: MLA1 (the original RFM definition of MLA), MLA2b (angle between calcaneus and MTH head, navicular tuberosity as vertex), MLA3b (angle between vector binding the calcaneus to the navicular tuberosity and the vector binding the MTH head to the metatarsal base), MLA4 (angle between calcaneus ground projection and MTH head, navicular tuberosity as vertex).

Results: Bland-Altman analysis shows better agreement between methods using MLA2b and Cal_Met angle, with differences between measures closer to zero and narrow standard deviations.

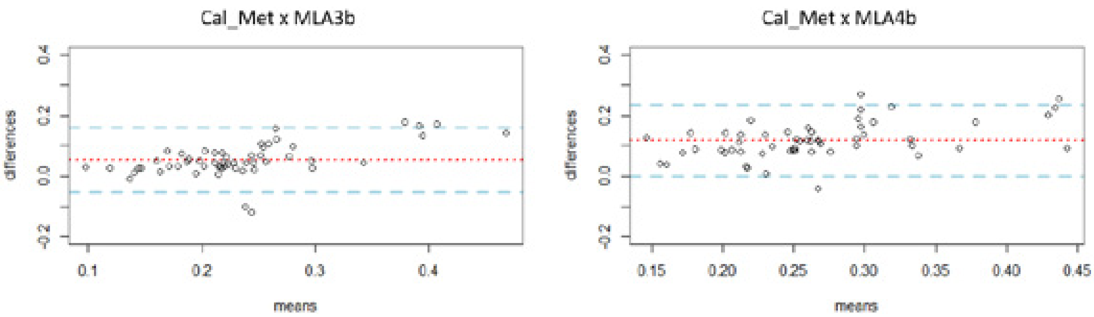

Figure 1- Bland-Altman plots of quasi-stiffness calculated using Cal_Met angle and using MLA3b (left) and MLA4b (right). Red lines represent the average of differences and blue lines represent two standard deviations of the differences.

Conclusions: The new proposed MLA3 definition (using the navicular tuberosity instead of the *sustentaculum tali*) have already shown to be reliable [3] and do not differ significantly when used for quasi-stiffness calculation when compared to the previous method [2].

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Marker placement sensitivity in the Oxford and Rizzoli Foot Models

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INTRODUCTION: Marker-based multi-segment foot models, like the Oxford Foot Model (OFM) and Rizzoli Foot Model (RFM), are prone to errors because of the small distances between markers. Hence, inconsistent marker placement can substantially influence the calculated kinematics [1]. Repeatability of multi-segment foot models has been studied frequently [2]. In these studies all markers were replaced simultaneously, thereby mainly testing the performance of the testers. However, insight in critical misplacement of individual markers on foot kinematics should be known.

AIM: Quantify the effect of controlled marker misplacement on kinematics as measured by OFM and RFM.

METHODS: A combined OFM and RFM marker set was placed on the right foot of one female participant (age: 24years, EU foot size: 39) and static pose data was collected. Data processing (Matlab) was performed separately for each foot segment (i.e. hindfoot, midfoot and forefoot) of OFM [3] and RFM [4]. First, the foot coordinate system was determined as defined in Cappozzo et al.[5]. Next, one by one, each marker on the segment was virtually moved ±1cm over the x, y and z axis of the foot coordinate system in steps of 1mm. This resulted in six times ten replacements for each marker. For every replacement the change in segment orientation was calculated with respect to the reference pose in which no markers were moved. For each marker, a linear fit was made between -5 and 5mm displacement to express the sensitivity of the segment orientation in each plane in degrees per 1mm replacement.

RESULTS: For most of the marker replacements the sensitivity was less than 0.3°/mm. However, some high values (>0.9°/mm) were found for markers in every segment of both OFM and RFM. In OFM, largest effects were found in the hindfoot segment orientation, mainly when replacing one of the two markers on the posterior aspect of the calcaneus in medio-lateral direction (Fig.1A). In RFM, the forefoot segment demonstrated the largest effect, which originated from replacing the marker located on the base of the 2nd metatarsal (Fig.1B).

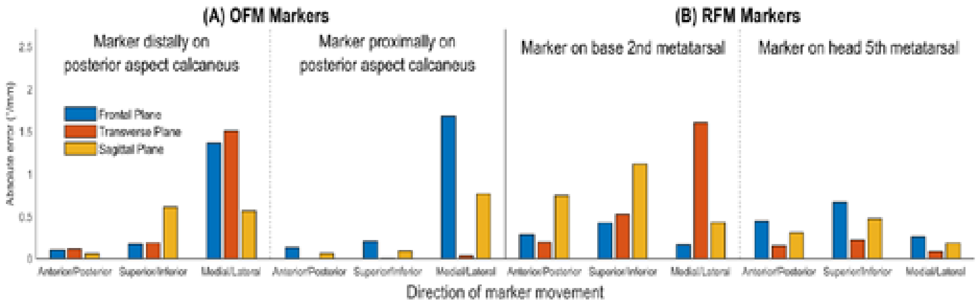

Figure 1. Absolute errors on the hindfoot orientation of OFM (A) and the forefoot orientation of RFM (B) when moving a selection of markers

DISCUSSION & RELEVANCE: This study shows that small marker misplacements can lead to large effects in multi-segment foot kinematics. Moreover, it points out OFM and RFM markers of which a consistent placement is most critical for obtaining repeatable kinematics. The magnitude of the effect of misplacements on the kinematics are likely depending on foot size and therefore a next step is to evaluate a range of sizes.

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Mechanical risk factors for predicting stress fracture in elite runners

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Bone Stress Injuries (BSI) are caused by repetitive fatigue loading on bones, are common in elite distance runners, and a common reason for missed competition and training. Nearly 40% of all BSIs in runners occur in the feet, and foot biomechanics during landing may play an important role in this injury. Our goal was to determine the degree to which dynamic foot loading measures could predict the occurrence of foot BSIs in elite runners. We hypothesized that runners who exerted more uneven plantar loads while walking, running, and completing athletic movements would show higher rates of BSI in the future.

Forty collegiate runners were recruited for this prospective observational study (16 females, 24 males). Foot plantar pressure was measured using a validated insole pressure monitoring system (Novel Pedar). Athletes completed different movements and drills (walking, running, cutting, shuttle run, jumping) while the insole monitoring system measured contact area, force, pressure, and force-time integrals in seven subregions of the foot. Incidence and location of BSIs were tracked during the remaining years that each athlete competed at the collegiate level (up to four years). T-tests were used to compare plantar pressure data between the groups. Incident BSI in the foot was predicted using a forward binary logistic regression analysis. Candidate predictor variables were identified through stepwise discriminate analysis and t-tests. Only plantar pressure-related data were included in the present analysis.

Incident BSI in the foot was predicted by the force-time integral of the hindfoot during a shuttle run and maximum mean pressure of the first metatarsal (MT1) during treadmill walking ($R^2 = 0.714$, Table 1). This model was able to correctly predict all 35 athletes without an incident BSI, and 3 out of 4 athletes with one. Those with incident BSIs in the foot also had higher peak and maximum mean pressures in the hindfoot during running.

Athletes with an incident BSI in the foot had higher maximum mean pressures of MT1 during treadmill walking, and had lower force-time integrals of the hindfoot during a shuttle run. We expect that the lower impulse of the hindfoot during the shuttle run leads to higher impulses in the forefoot regions. Together, the higher loads directed towards the forefoot during athletic movements may contribute to BSI in the foot. Additionally, the higher pressures in the hindfoot during running may indicate a difference in running mechanics in the incident BSI group.

Table 1. Mean values of predictor variables in athletes with and without incident BSI in the foot.

	(Male/Female)	Mean height (in)	Mean Weight (lbs)	Mean BMI	Mean force-time integral of hindfoot during shuttle run (N*s)	Mean max mean pressure of MT1 during treadmill walking (kPa)
Incident BSI	0/4	66.0 *(SD: 2.83)*	125.3 *(SD: 16.9)*	20.1 *(SD: 1.0)*	1.99 *(SD: 1.02)*	21.02 *(SD: 3.24)*
No Incident BSI	24/11	70.3 *(SD: 3.24)*	145.9 *(SD: 16.9)*	20.7 *(SD: 1.5)*	3.56 *(SD: 1.59)*	15.43 *(SD: 3.84)*

Table 2. Mean comparisons of athletes with and without incident BSI

	Peak pressure of hindfoot during running (kPa) **p = 0.036**	Maximum mean pressure of hindfoot during running (kPa) **p = 0.027**
Incident BSI	31.53 *(SD: 4.37)*	21.49 *(SD: 2.92)*
No Incident BSI	24.52 *(SD: 9.56)*	16.42 *(SD: 6.29)*

Motion of all foot bones under controlled vertical load from series of weight-bearing CT scans

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The human foot complex is a multi-joint mechanism, which is fundamental for the interaction between the lower limb and ground during locomotion. Despite the literature on the topic [1-3], a comprehensive description of the 3D foot kinematics under loads including all bones is still missing. This work aims at filling this gap, through a CT-based investigation of the foot motion under weight-bearing conditions.

We investigated a foot from a donor with no history of musculoskeletal pathology. The leg was casted in extended position, while the foot and ankle were free to move. The specimen was kept vertical in the weight-bearing CT scanner and axially loaded by half the donor weight. Fifteen combination of foot dorsi-plantar flexion and prono-supination angles were imposed by custom wedges; two additional poses were added by rotating the leg internally and externally, for a total of 17 loaded poses. Weight-bearing CT scans were segmented by a semiautomatic procedure and the position and orientation of each bone was described using functional reference systems and specific cardan sequences defined for this study, with sub-millimeter and sub-degree accuracy.

Figure 1 shows the reconstructed foot motions, expressed with respect to the talar reference system to better emphasize the relative displacement among the bones. The first row shows the dorsi-plantar flexion at zero degree of pronation, the second row the prono-supination at zero degree of flexion, and the third row shows the internal-external rotation of the leg about the neutral configuration.

Results suggest a decoupling between prono-supination and dorsi-plantar flexion. During prono-supination, talus does not move relatively to the tibia while the other bones show small but significant spatial relative motion. During dorsi-plantar flexion, the relative displacement among the bones in the foot is minimum, while the talus describes a well-defined spatial trajectory with respect to the tibia. The internal-external rotation of the leg results instead in a relevant complex spatial motion involving all the foot bones. The same results are observed by investigating the relative motion components obtained using the functional reference systems.

This work reveals the complexity of the motion among the foot bones: while the talar and subtalar joints provide the main foot mobility along two almost decoupled directions, the other joints behave in a synergic way to support more complex loading conditions and are thus essential to the functionality of the foot. Future work will extend the present analysis to five additional specimens.

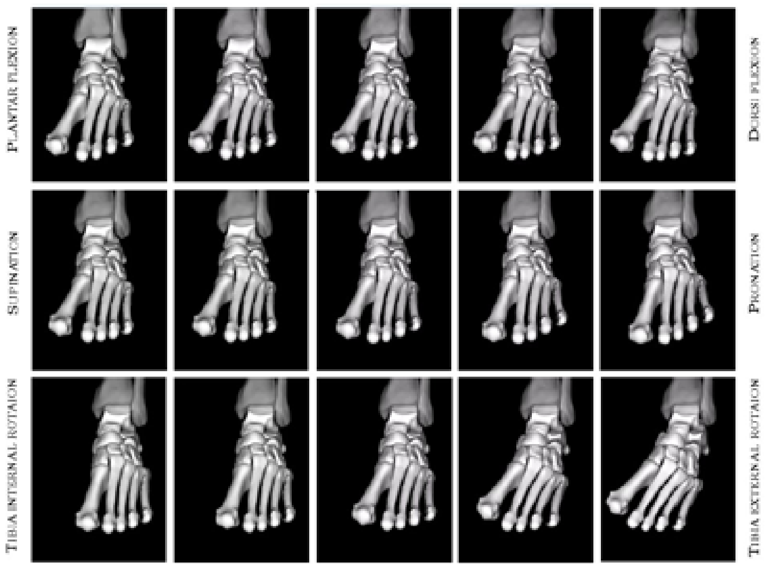

Figure 1. 3D kinematics of the foot bones shown with respect to the talus, kept fixed: dorsi-plantar flexion (first row), prono-supination (second row), and internal-external tibial rotation (third row).

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Multi-segmented foot model applied in Star Excursion Balance Test assessment

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Background: The Star Excursion Balance Test (SEBT) is a commonly used tool for assessing dynamic balance performance in clinical and research settings [1]. It has been shown, that the SEBT reliably detects balance deficits, that it is related to lower limb injuries and that its performance can be influenced by training [1]. SEBT performance is not only influenced by pathologies or training, also foot types and available lower extremities' range of motion (ROM) play a role [2,3]. So far, the contribution of the foot and ankle in maintaining balance during the SEBT has only been analyzed with a one-foot segment kinematic model. However, a more detailed analyses of the role of the foot in maintaining balance during SEBT may provide additional insights [1]. The aim of this study was to analyze the kinematic motion of five foot segments during the SEBT. **Methods:** The SEBT performances of 11 healthy participants (age: M = 23.18 years) were recorded with a Qualisys motion capture system and post-processed with Visual3D. For comparison, a two-limb stance (2-limb) was measured. Five foot segments were defined by 21 markers per foot, in accordance to the Ghent Foot Model (GFM) [4]. Foot segment angles between Tibia and rearfoot (RF_Tibia), rearfoot and midfoot (MF_RF), midfoot and medial forefoot (MFF_MF) and midfoot and lateral forefoot (LFF_MF) were calculated. The segment's amount of motion during the SEBT and two-limb stance was presented by the cumulative range of motion (cumROM). **Results:** The results show, that the segments have an increased cumROM during SEBT compared to a two-limb stance in all three different anatomic planes (Figure 1). The medial and lateral forefoot demonstrated the largest increases in cumROM, when comparing SEBT to 2-limb stance. **Conclusion:** The present findings suggest, that the foot segments are involved in dynamic balance tasks and demonstrate the need to look more carefully into the role of medial and lateral forefoot in maintaining balance. Especially in cases of foot and ankle pathology, these structures should be taken into account when analyzing dynamic balance performance.

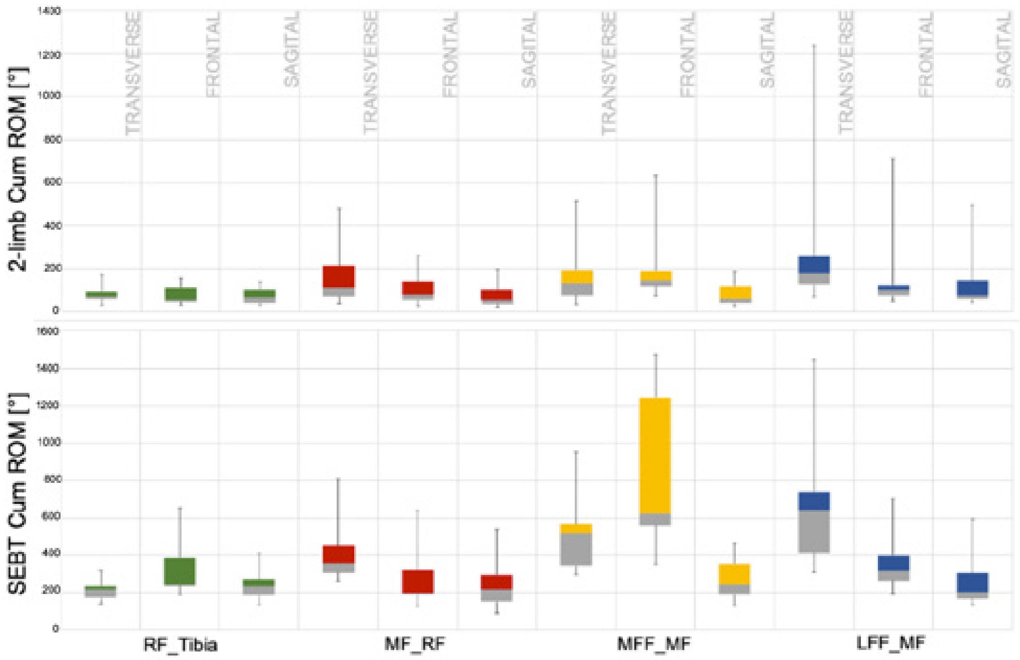

Figure 1. Cumulative ROM of RF_Tibia, MF_RF, MFF_MF, and LFF_MF during 2-limb stance and SEBT.

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New 3d angular measurements of foot bones in weight-bearing: the technique and preliminary clinical cases

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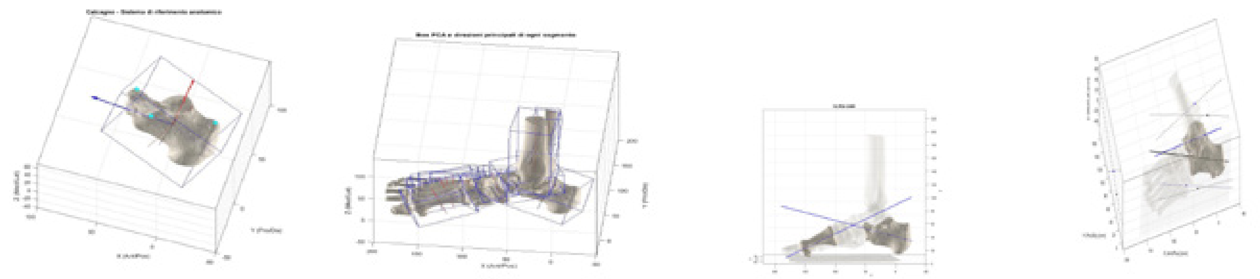
The foot is comprised of 26 bones, connected by several joints, the relative orientation of which is significantly affected by the loading conditions [1]. X-ray based measurements have been traditionally used to estimate skeletal posture and alignment between segments [2], but these are 2D projections and operator-dependent, requiring manual identification of the relevant anatomical landmarks. Modern weightbearing CT devices based on cone-beam tomography (CBCT) allow objective quantification of the foot skeletal posture in 3D in different loading postures, e.g. in upright single or double leg weight-bearing [3,4]. The present study aims at proposing a novel method for the automatic measurement of 3D orientation of foot and ankle segments from CBCT scans. The method has been exploited in our Institute for the analysis of the effect of different loading conditions and of a number of common foot pathologies.
According to the proposed method, the DICOM files obtained via CBCT scanning ('OnSight 3D Extremity System', Carestream, Rochester, NY) of the foot are segmented (Mimics, Materialize) and the corresponding STL 3D models of each bone are used for the analysis. A global reference and an anatomical local reference frames are established for the entire foot and for each bone; for the latter Principal Component Analysis (PCA) was also used. Absolute and relative orientations between bones in 3D and as projections in the three anatomical planes, distances and dimensions, can be calculated (Figure 1) also by using anatomical landmarks and axes identified automatically.



(A) (B) (C) (D)

Figure 1: (A) definition of the calcaneus reference frame based on anatomical landmarks; (B) complete set of bone reference frames based on PCA; (C) how a traditional 2D views from radiographs can be represented with a corresponding lateral plane projection of 3D axes; (D) a full 3D view of the three traditional projection angles, together with a original 3D angle between long axes of talus and calcaneus.

The present technique has been applied for the objective automatic measurement of bone alignments in a number of patients with foot alterations, such as diabetic foot, pre- and post-op flat foot, and arthritic ankle.
The novel technique allows multi-planar measurements using 3D models of the foot bones and has revealed to be more repeatable and more anatomically accurate than standard X-ray based measurements. While segmentation of bones is still a semi-automatic time-consuming procedure, the automatic definition of landmarks, axes and reference frames removes any subjective variability and bias from the analysis of foot bone architecture, which can now be investigated in 3D and in different weight-bearing conditions, thus opening the door to a number of new biomechanical and clinical investigations [3,4,5].

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Novel 3D printing orthosis with propulsion system increases stride length in children with cerebral palsy

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Introduction

Hinged AFO (HAFO) is a orthosis which blocks plantar flexion without restricting ankle dorsiflexion and is commonly prescribed for children with Cerebral Palsy (CP) and equine gait pattern – excessive plantar flexion caused by spasticity and/or contracture of plantar flexor muscles [1]. Although the orthosis promotes benefits, its use restrains the action of the plantar flexor muscles and affect the puff-off phase of the gait, restricting the movements of the ankle and the energy generated to advance the lower limb forward [2]. Consequently, an inefficient push-off might causes changes in the temporal space parameters of the gait, for example, in the stride length. Considering that children with CP might have their push-off affected by an impaired plantar flexor muscles, an orthosis with external propulsion system can compensate the muscle inefficiency of these individuals. Therefore, the present pilot study objective was to verify whether there is a difference between conventional polypropylene HAFO and 3D printing HAFO, with ankle external propulsion system, in stride length during the gait of children with CP.

Methods:

A quasi experimental study was conducted with six children recruited in Associação Mineira de Reabilitação (AMR) (CAAE: 22988719900005149). The inclusion criteria were (1) age between 5 and 17 years old; (2) diagnostic of hemiplegic spastic CP; (3) use daily unilateral HAFO; (4) have not undergone botulinum toxin and/or orthopedic surgery on lower limb in the last six months. Children were excluded if they report pain or discomfort during data collection. The children were instructed to walk at their self-selected walking speed in a 5 meters' walkway in two conditions, conventional HAFO and 3D printing HAFOs with external propulsion system (Figure 1). Stride length was computed with a tridimensional motion analysis system. A dependent T-test calculated the difference in stride length between conditions, and the results were tested for the Minimum Clinically Important Difference (MCID) as a threshold for determining when meaningful changes occur for CP population [3]. A significance level of 0.05 was considered and the results were classified as clinically relevant if they target a MCID of 3.6% for medium and 5.8% for large effect sizes.

Figure 1: Children with CP with the HAFOs used. **A**: 3D printing with external propulsion system. **B**: Conventional.

Results:

The results showed that stride length was 4.8% higher with the 3D printing HAFOs, which achieve a medium effect when compared with the conventional HAFO condition, but no statistical difference was found (3D printing HAFO: mean = 1.15 m; SD = 0.28; Conventional HAFO: mean = 1.10 m; SD = 0.24; 95% CI = -0.17 – 0.08; p = 0.36).

Conclusion:

Improving the gait pattern and its spatiotemporal parameters, making it more efficient, is an essential goal in the treatment of children with CP, since mobility is associated with functional independence and child participation in their different contexts [4]. The moderate effects found in gait stride length during comparison with both orthoses indicates that, besides the non-statistical difference a clinically difference was found. Therefore, the present pilot study indicates that, even analyzing just six children with CP, the orthoses were effective in generating a significant clinical change in CP, improving gait stride length in this population.

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Obesity, muscle quality and plantar fascia thickness in healthy adults

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Abstract

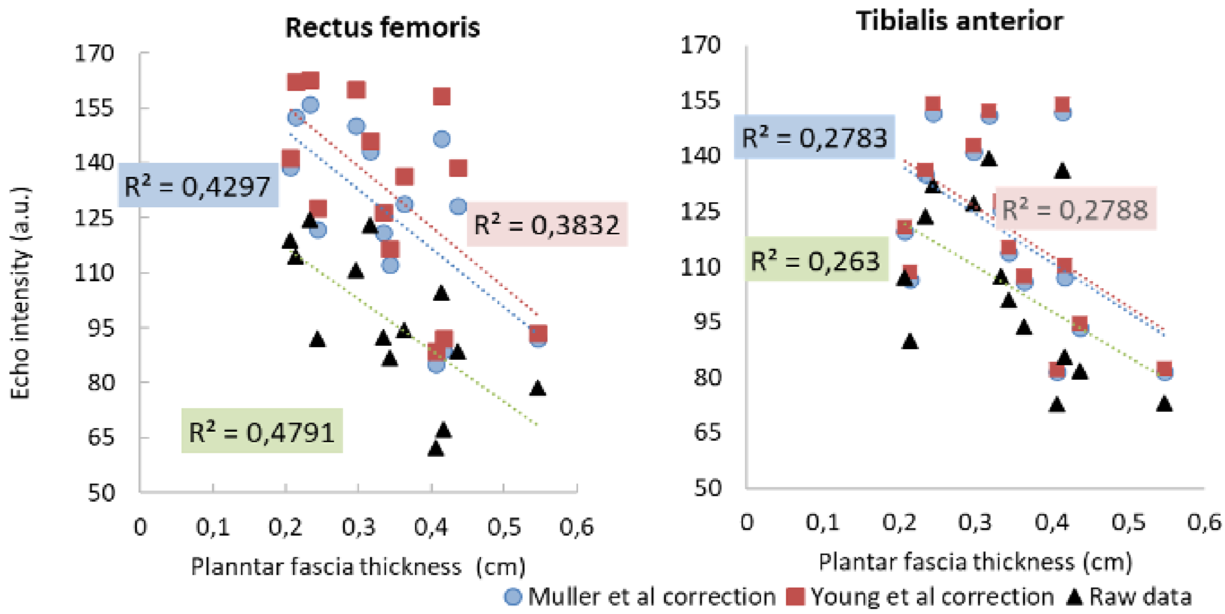
Background: Thickening of the plantar fascia and loss in muscle quality have been reported for obese patients compared to normal weight healthy controls [2,3]. These findings are thought to be related to the accumulation of fat in the muscle and to the glycation of associated connective tissue structures. Ultrasound ecointensity (EI) is a useful tool for estimating intra-muscular fat non-invasively, however care needs to be taken to account for the confounding effect of subcutaneous fat on EI [1,4]. While an association between plantar fascia thickness (PFT – a measure of tissue glycation) and muscle quality may be expected across individuals with different BMI, this relationship has not yet been tested.
Objectives: To evaluate the associations between muscle quality, PFT and body mass index (BMI) in a sample including healthy underweight, normal weight and overweight obese individuals.
Methods: 60 male subjects were evaluated for BMI. From this sample the 14 subjects closest to the bottom and top extremes of BMI were assessed for muscle quality and plantar fascia thickness. Age varied from 20 to 34 years and BMI from 18.2 kg / m² to 35.0 kg / m². Ultrasound images were collected from anterior tibialis (TA), rectus femoris (RF) and PFT. EI of the muscles was obtained and corrected for the effect of subcutaneous fat thickness using an equation developed by us (Neto Muller et al. in press) [1].
Results: There were no significant correlations between BMI and PFT or EI of the TA and RF (Table 1). However, moderate correlations were observed between PFT and EI for both the RF ($r = 0.655$, $p = 0.01$) and TA muscles ($r = 0.528$, $p = 0.05$).
Discussion: In contrast to what has been shown in the literature [2], BMI was not associated to a loss in muscle quality or increase in plantar fascia thickness, despite the wide variability in BMI in our sample. Our results suggest that obesity is not necessarily associated to fat invasion in the muscles or tissue glycation. These results might be associated to activity level of participants, leading to the existence obesity (increase in BMI) in the absence of metabolic disorders. Interestingly, thickening of the plantar fascia was correlated to better muscle quality in our sample, suggesting that there might be a common factor that drive these adaptations (exercise?).
Conclusions: Our study shows no association between muscle quality loss or plantar fascia thickening with increasing BMI in a range comprising underweight and obese individuals. The inverse relationship between PFT and EI requires further investigation but might be related to the amount of physical exercise of participants.

Table 1. Descriptive and inferential statistics (r of Pearson's correlation) of parameters related to obesity (1, 2 and 3) and muscle quality (eco-intensity, EI) of the anterior Tibial (TA) and rectus femoris (RF) muscles. Raw EI values are shown and corrected for the effect of the subcutaneous fat thickness.

	Median	Mean (SD)	Variation (Min – Max)	Correlation				
				1	2	3	4	5
1 1. BMI (kg.cm^{-2})	25.8	26.7 (4,9)	18.4 – 34.4	-				
2 2. BF (%)	27.9	24.8 (11,8)	5.4 – 40.5	0.86	-			
3 3. Ratio W/Hip	0.84	0.87 (0,07)	0.8 – 1.0	0.88	0.83	-		
4 4. Ratio W/Hgt	0.5	0.51 (0,08)	0.4 – 0.6	0.94	0.92	0.94	-	
5. PFT (cm)	0.34	0.34 (0,10)	0.21 – 0.55	0.11	-0.13	0.24	0.10	-
EI TA (a.u)	117	119 (25)	81.5 – 152	0.02	0.17	-0.003	0.014	-0.528*
EI RF (a.u)	129	126 (24)	85.1 – 156.2	0.24	0.29	0.22	0.17	-0.655**

BMI= body mass index, BF = body fat, Ratio W/Hip, EI = echointensity, TA = Tibial Anterior, RF = Rectus femoris, PFT = Plantar Fascia Thickness.. *$p<0.10$, ** $p<0.05$.

Figure 1. Relationship between plantar fascia thickness and EI estimates of muscle quality. Greater thickness of the plantar fascia was associated with better muscle quality (lower EI) for the RF (p<0.05) and the TA (p≤0.06). n = 14. Note the relationship was present regardless the correction applied.



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Objective mechanical measures predict post-traumatic OA risk after intra-articular fracture of the hindfoot and ankle

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Background: Post-traumatic osteoarthritis (PTOA) after intra-articular fracture (IAF) of the hindfoot and ankle commonly occur within 2 years of injury. Contradictory clinical evidence has found both the severity of the initial injury and the accuracy of surgical reduction to be important determinants of this rapid progression to PTOA [1-5]. Recently, patient-specific techniques for objectively quantifying the fracture severity and the accuracy of surgical reduction have been developed. The objective of this study was to use these measures to determine the relationships between the acute fracture severity, the accuracy of surgical reduction, and the PTOA risk after IAF of the ankle and hindfoot.

Methods: Forty-nine patients with IAFs of either the tibial plafond in the ankle (16) or the calcaneus in the hindfoot (33) were enrolled in this IRB-approved study. Patients were selected for having both pre- and post-operative CT imaging with ≥18 months radiographic follow-up. Kellgren-Lawrence grades ≥2 were considered indicative of PTOA. Fracture severity was determined from pre-operative CT scans using previously validated, objective methods based on the energy liberated in fracture creation [2,6]. Discrete element analysis was used to evaluate surgical reduction accuracy by computing deleterious contact stress over-exposure from post-operative CT scans (Figure 1). Predictive capabilities of both metrics were analyzed using receiver-operating characteristic (ROC) curves and Spearman's correlations.

Results: Acute fracture severity (FS) metrics and maximum contact stress over-exposures (CSOs) significantly correlated with the degree of PTOA severity in both the ankle (FS: ρ0.82, p<0.001; CSO: ρ0.65, p=0.007) and hindfoot (FS: ρ0.52, p=0.002; CSO: ρ0.48, p=0.004). A combined measure of the FS and CSO had an AUC of 1.00 in the ankle and an AUC of 0.88 in the hindfoot, indicating perfect and excellent delineation of cases that did / did not develop PTOA, respectively. CSO was significantly correlated with FS in both the ankle (ρ0.52, p=0.04) and hindfoot (ρ0.35, p=0.05, Figure 2).

Discussion: Presently, clinical practice and research into optimal IAF treatment rely upon subjective measures of injury severity and reduction accuracy to control data and guide surgical management. As found in the prior literature, both the surgical reduction accuracy and the fracture severity were strongly predictive of PTOA risk and severity. The CSOs were more strongly correlated with PTOA, though strong significant correlations were also found with the severity. This suggests that the accuracy of surgical reduction in both ankle and hindfoot remain paramount despite the inherent PTOA risk associated with the injury itself.

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Figure 1. Fracture severity and contact stress over-exposure models for the ankle and hindfoot (shown as left and right respectively for each PTOA designation). Inferior views of the tibia are shown for the ankle while superior views of the calcaneus are shown for the hindfoot. Both fracture severity and contact stress over-exposure were significantly higher in cases that developed PTOA.

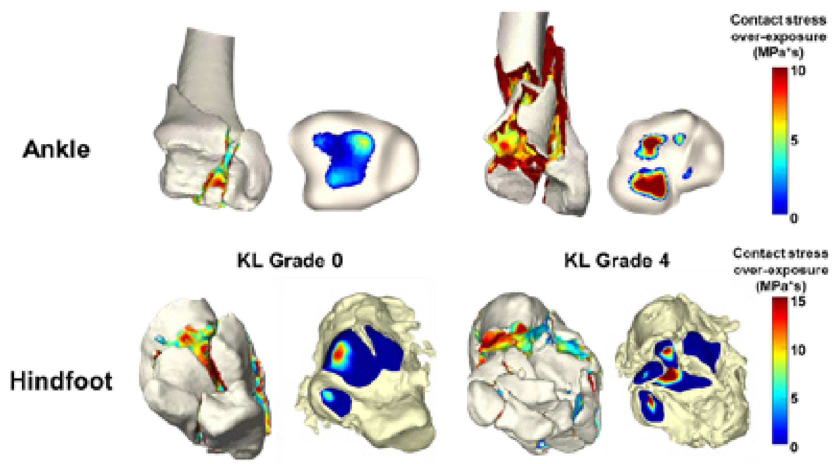
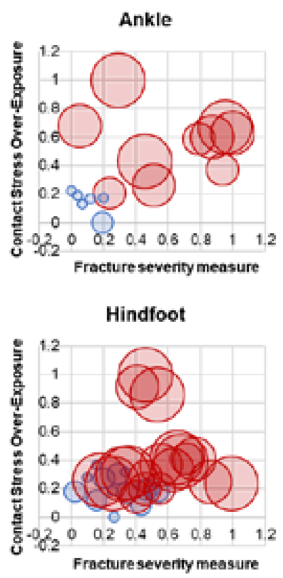


Figure 2. Fractures with lower severity and contact stress over-exposure had lesser degrees of PTOA (KL grades 0&1 shown as smaller blue bubbles and KL grades ≥2 as larger red bubbles).



Open kinematic chain motion of the sesamoids in dorsiflexion

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Introduction: The tibial and fibular sesamoids are two small bones embedded in the medial and lateral heads of the flexor hallucis brevis tendon at the first metatarsophalangeal joint (MTPJ1). Published data quantifying sesamoid kinematics as a function of MTPJ1 motion are limited [1]. We aimed to quantify sesamoid motion in intact, non-embalmed cadavers without evidence of osteoarthritis or hallux rigidus, and to compare three measurement techniques used for quantifying MTPJ1 range of motion (ROM) in predicting the observed sesamoid motion.

Methods: Ten fresh-frozen cadaveric foot specimens were dissected. The MTPJ1 ROM was determined from a goniometer and from images collected from a BV-Pulsera fluoroscope (Philips, Netherlands). Specimens were then scanned in three loading configurations (neutral and maximum dorsiflexion, plus an intermediate position) using a pedCAT cone-beam CT scanner (Curvebeam, Hatfield PA; voxel size = 0.3 mm). The sesamoids and first metatarsals were segmented. Bone kinematics between subsequent scans were determined via co-registration of the datasets. Sesamoid kinematics were expressed as the position of each bone's center of mass in a coordinate frame based on the first metatarsal anatomy. Only descriptive statistics are presented.

Results: In the sagittal plane in both neutral and maximally dorsiflexed positions, the angle of tibial sesamoid was greater on average than the fibular sesamoid (Figure 1A). ROM of the tibial and fibular sesamoids in the sagittal plane were comparable (30.20 ± 14.29° vs. 35.8 ± 10.64°). In the transverse plane, both sesamoids trended towards the body's midline from neutral to maximum dorsiflexion positions (Figure 1B). The distance between the two sesamoids remained constant throughout ROM. Of the three measurement techniques (goniometer, fluoroscopy, and CT), MTPJ1 ROM from CT was best correlated with sesamoid ROM (Figure 2).

Conclusion: We demonstrated the sesamoids' anterior angular rotation on the metatarsal head during dorsiflexion. In the sagittal plane, the anterior excursion of the tibial sesamoid was greater than that of the fibular sesamoid, which could cause greater force to be on the tibial sesamoid in dorsiflexion and contribute to the greater incidence of tibial sesamoid stress fractures [2]. Quantitative data of the normal motion of sesamoids are necessary to understand how abnormal or diminished motion may contribute to forefoot pain. Further, current MTPJ1 replacements do not always consider the sesamoids in their design. This study may help to inform the development of MTPJ1 implants that are sesamoid-preserving.

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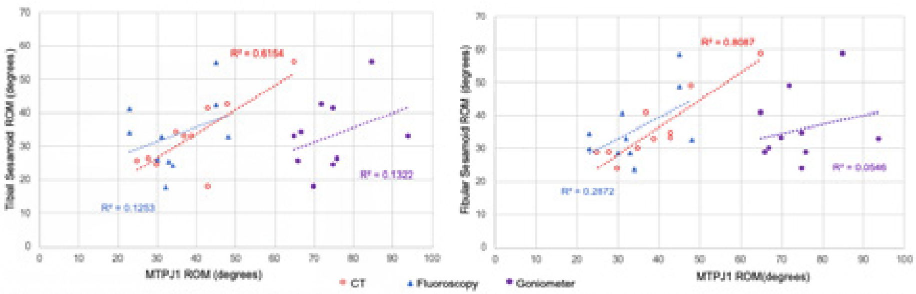

Figure 2. Correlation of **(A)** tibial and **(B)** fibular sesamoid motion with ROM calculated with the goniometer, in fluoroscopy, and in CT.
head. **(B)** Plantar view demonstrates medial-lateral excursion.

People with diabetes mellitus and peripheral neuropathy have limited ability to plantarflex their foot and ankle during heel rise tasks

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Background: Normal foot mechanics during propulsive weight-bearing tasks (e.g. walking, stairclimbing) require coupling of foot and ankle plantarflexion. People with diabetes mellitus and peripheral neuropathy (DMPN) have reduced foot and ankle plantarflexion during a single-limb heel rise [1], but how foot and ankle plantarflexion is coupled together during the heel rise task is unknown. Understanding coupling of foot and ankle plantarflexion during high load (single-limb heel rise) and low load (double-limb heel rise) tasks would have implications for treatment strategies to improve propulsive weight-bearing performance. The purpose of this study was to compare coupling of foot and ankle plantarflexion in people with DMPN and healthy controls during single- and double-limb heel rise.

Methods: Fifty-eight participants with DMPN, 20 BMI-matched older controls, and 23 BMI-matched younger controls performed single- and double-limb heel rise. Foot (forefoot on hindfoot) and ankle (hindfoot on shank) kinematics were examined using 3D motion analysis. All groups were divided into two subgroups according to their heel rise performance: 1) able to plantarflex both foot and ankle and 2) unable to plantarflex either or both foot and ankle during heel rise task. A Chi-square and Fisher's exact test was used to analyze the difference of proportions of the subgroups between DMPN, older controls, and younger controls.

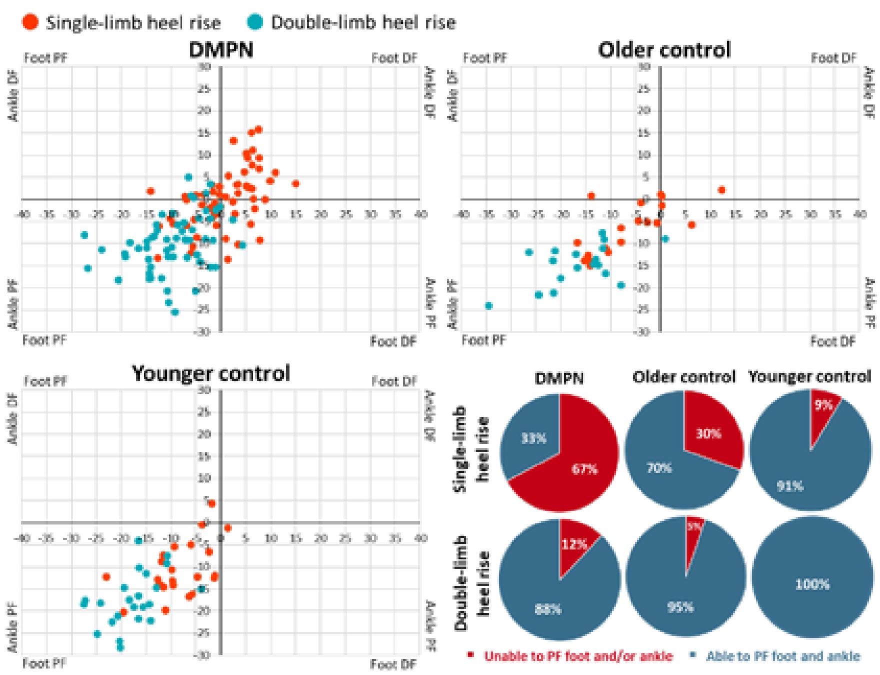
Results: People who were unable to plantarflex either or both foot and ankle during single-limb heel rise were significantly greater in DMPN (67%) compared to older (30%) and younger (9%) controls ($p<0.01$), but not significantly different in older compared to younger controls ($p=0.12$). When the load was reduced with the double-limb heel rise, there was no difference between groups in the percent of people who could not couple foot and ankle plantarflexion (12% of people with DMPN, 5% of older controls, and 0% of younger controls, $p=0.17$; Figure 1).

Discussion: People with DMPN are more likely to exhibit abnormal coupling of foot and ankle plantar flexion during a single-limb heel rise compared to controls. DMPN and controls could restore the coupling of plantar flexion when the load was reduced.

Conclusion: Inability to couple foot and ankle plantarflexion during a single-limb heel rise task with the restoration of coupling during lower load double-limb heel rise may identify people who would benefit from physical therapy intervention to improve strength and function.

Acknowledgment: This study was funded by the National Institute of Diabetes and Digestive and Kidney Diseases of the National Institutes of Health (R01 DK107809).

Figure 1. Coupling of foot and ankle plantarflexion during single- and double-limb heel rise



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Perception of mothers of children with cerebral palsy about the benefits of their children ankle foot orthoses

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Introduction

The use of ankle foot orthoses (AFO) is fundamental in rehabilitation process for children with Cerebral Palsy (CP) with severe motor impairment. AFO are indicated in prevention of deformities and muscle shortenings through the stretching tension apply on musculo-tendon complex. Consequently, AFO can increase ankle range of motion, decreasing future deformities or even a surgical intervention. However, this device is not utilized properly or even abandoned by family members for lack of understandment of its benefits. Therefore, family-centered approach becomes an essential strategy to promote the integration and participation of family members in rehabilitation process.

Objective: Understand the perception of mothers of children with CP about the benefits of their children's AFO.

Methods

Sample: A convenience sample of 22 mothers of children with CP participated in this qualitative study (CAAE 55502515.9.0000.5088).

Inclusion criteria: (1) age between 5 and 17 years old; (2) diagnosed with CP; (3) level IV and V of GMFCS; (4) use ankle foot orthoses for a minimum of one year.

Exclusion criteria: Complaining of constraint or discomfort during interview.

Procedures: A semi-structured interview was applied by a researcher in a private room with each mom separately (Figure 1).

Data analysis: Thematic content analysis technique was used to analyze the data.

Figure 1: Semi-structured Interview being applied by a researcher

Results

The main AFO benefits described were:

- the improvement of foot alignment;
- better mobility promotion regarding standing posture and changing steps during walking interventions at clinical practice;
- assists the prevention of deformities.

Conclusions

Although not all mothers interviewed understand the benefits provided by the use of AFO, they identified that the device helps to improve the positioning of the limbs and promotes greater stability of the child when standing, facilitating their mobility during therapy sessions. In addition, AFO assists the prevention of future deformities reducing the chances of possible surgical intervention. Therefore, a family-centered approach is necessary in an attempt to increase parents' perception about the benefits of their children AFO.

Acknowledgements

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PERCUTANEOUS CHEVRON/AKIN (PECA) VERSUS OPEN SCARF/AKIN (SA) OSTEOTOMY TREATMENT FOR HALLUX VALGUS: A SYSTEMATIC REVIEW AND META-ANALYSIS

BACKGROUD: The surgical treatment of hallux valgus presents several techniques described in the literature. Recently the percutaneous technique appeared as a less invasive option in the correction of the deformity and more and more used by the surgeons.

METHODS: The meta-analysis was performed through studies found from the systematic review of articles included in electronic databases (Medline, Scopus, Embase and the Cochrane Library) until June 2019 (Systematic Review Registry PROSPERO: CRD42018096613). A pooling analysis was synthesized from clinical outcomes such as visual analogue scale of pain (VAS) and AOFAS score, radiographic outcomes and evaluation of complications.

RESULTS: Finally, three studies met the inclusion criteria and were included in the qualitative analysis and metanalysis comparing open surgery using the Scarf and Akin (SA) technique versus the percutaneous Chevron and Akin (PECA). In the synthesis of the result, pain in the perioperative period was lower in the PECA group, without presenting differences between techniques in the radiographic result, or in the risk of complications. The PECA technique demonstrated longer radioscopy time when compared to SA. This study has some limitations. Only three studies were included in the systematic review, two of which was retrospective. Another limitation was the short follow-up time in the studies, which could interfere with the outcome. These factors can influence the risk of bias and lead to erroneous conclusions.

CONCLUSION: The PECA surgical method, compared with the SA method, was shown to result in less postoperative pain and have similar potential for radiographic correction. The PECA technique led to greater radiation exposure. Only two studies were included in the metanalysis. A multicenter study with the same design as that of the selected studies is necessary to confirm the results
obtained.

LEVEL OF EVIDENCE: Level I: High-quality prospective randomized clinical trial

KEYWORDS: Hallux Valgus; Minimally Invasive Surgical Procedures; Meta-analysis.

Percutaneous Distal Metatarsal Mini-invasive Osteotomy: Comparison between Standard versus Modified Intraosseous Approach - A Cadaveric Study

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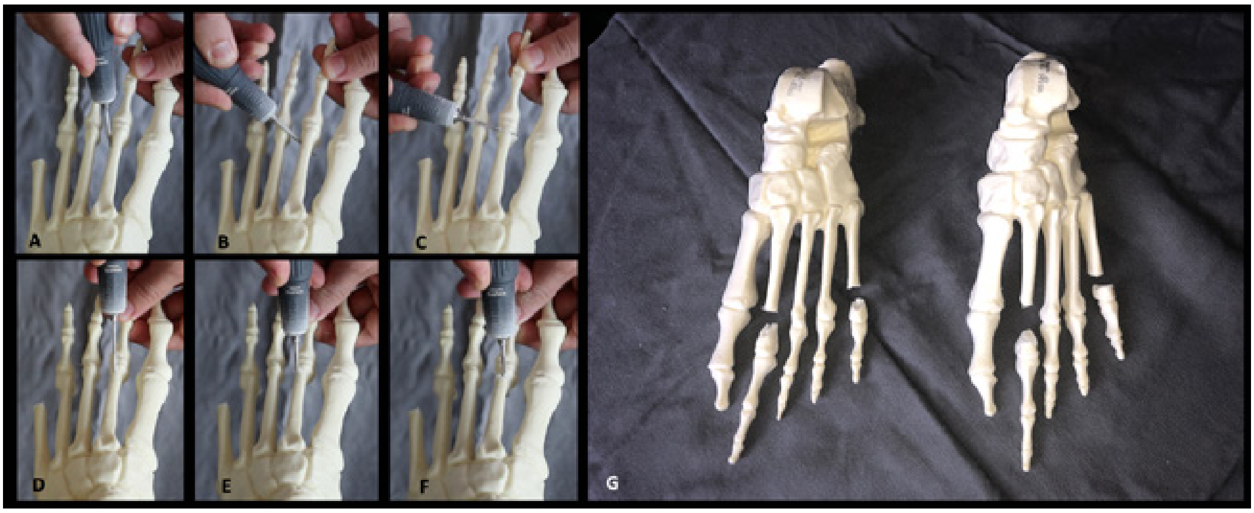
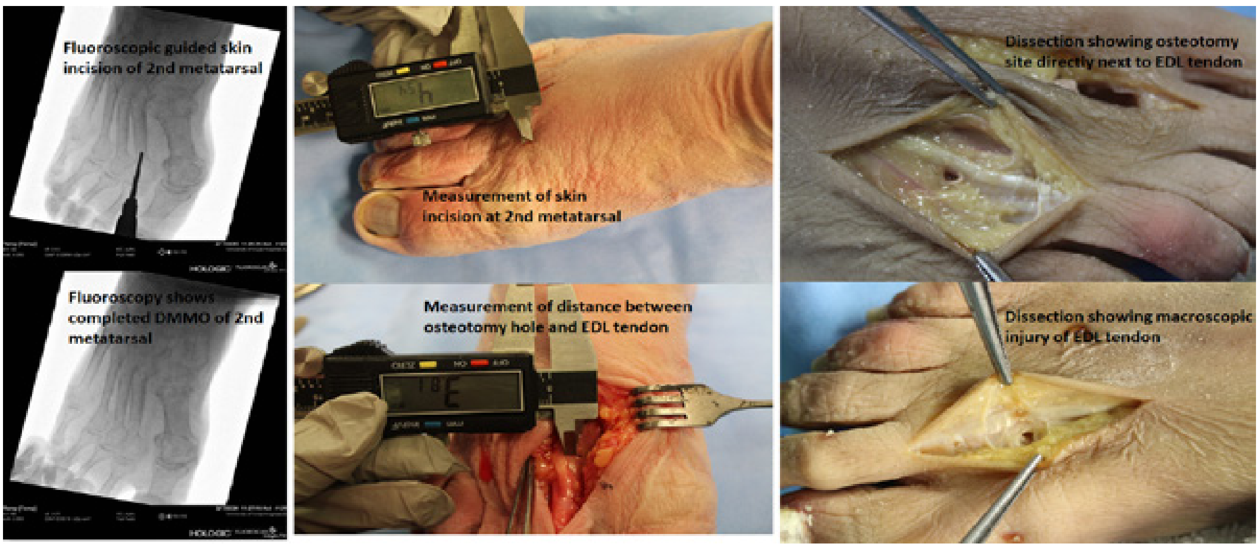
Introduction: The objective of this cadaveric study was to identify and compare the structures at risk of damage in standard versus modified intraosseous distal mini-invasive metatarsal osteotomy (DMMO). Our hypothesis was that the modified DMMO technique may be a safer, less complex procedure that could decrease the risk of iatrogenic injuries. [1,2,3]

Methods: 11 thawed fresh-frozen under the knee cadaveric specimens underwent DMMO of the forefoot. The modified technique proposed by this study enters the dorsal cortex (at 45 degrees) straight through to the plantar cortex followed by cutting the lateral cortices (panels D, E, F). The standard technique enters the right cortex (at 45 degrees) then cuts sequentially the right, plantar, medial and dorsal cortices (panels A, B, C).



After completion of the procedures, the cadavers were fully dissected to identify unintentional injury to structures such as extensor digitorum longus (EDL), flexor digitorum longus (FDL), extensor digitorum brevis (EDB) and metatarsal joint capsules (MJC). The distance from the osteotomy site to these structures was also recorded (Figure below).



Statistical analysis initially used descriptive tests. Numerical variables were presented by mean and standard deviation (SD), while categorical variables presented by frequencies, absolute and relative, were appropriated to the total sample size. The measurements recorded in this study were compared using non-paired t-test. Values of median, minimum and maximum were also presented.

Results: The most common injury by modified DMMO approach was the EDL tendon with 27% of the specimens having a macroscopic injury compared to 18% in the standard group. However, the standard group demonstrated 27% of its specimens having injury to the MJC and 9% of its specimens having injury to EDB tendon compared to 0% injury to those structures in the modified group. There was also a statistically significant difference between the distance of the osteotomy site of 6.08 ± 3.99 mm from the dorsal metatarsal head articular surface (DMHAS) in the standard group and 9.92 ± 3.42 mm from the DMHAS in the modified group ($p=0.02$).

Conclusion: Our cadaveric study demonstrated that the most frequently injured structure was the EDL tendon with both DMMO techniques used. Intra-articular positioning of the osteotomy was more frequently observed in the standard technique. Given our results, it appears the modified method could be a safer, less complex alternative to the standard DMMO technique, especially for the inexperienced surgeon.

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Peripheral Neuropathy, Claw Toes, Intrinsic Muscle Volume, and Plantar Aponeurosis Thickness in Diabetic Feet

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Introduction: The objective of this study was to explore the relationship between peripheral neuropathy, claw toe deformity, intrinsic muscle volume (IMV), and plantar aponeurosis (PA) thickness using computed tomography (CT) images of diabetic feet. It is hypothesized that claw toes are caused by an imbalance between the extrinsic and intrinsic foot muscles [1]. However, this hypothesis has been challenged [2,3]. Additionally, there is some evidence of a relationship between the presence of claw toes and PA dysfunction [4] and a thicker PA in diabetic patients relative to controls [5].

Methods: From an initial cohort of over 220 subjects with diabetes, ten subjects with Type-2 diabetes were randomly chosen in each of the following four groups: 1) peripheral neuropathy with claw toes (N+C+), 2) peripheral neuropathy without claw toes (N+C-), 3) non-neuropathic with claw toes (N-C+), and 4) non-neuropathic without claw toes (N-C-). Subjects were matched for sex, age, and body mass index. The intrinsic muscles of the foot were segmented from processed CT images. PA thickness was measured in the resliced sagittal plane at 20% of the distance from the calcaneus to the second metatarsal. Linear mixed-effects regression was used to test for significant differences.

Results: Neuropathy was associated with a mean 19,857 mm^3 decrease in IMV (p=0.039), while claw toe deformity was associated with a mean 25,104 mm^3 decrease in IMV (p = 0.008). Subjects with both neuropathy and claw toe deformity (N+C+) had significantly smaller IMV compared with N+C− (p=0.019) and N−C− (p=0.015). The interaction between neuropathy and claw toe deformity was not significant for IMV (p=0.08, Figure 1). Neither the presence of neuropathy nor the presence of claw toe deformity by itself had any significant between-group differences in the mean PA thickness. However, the interaction between neuropathy and claw toe deformity was significant (p=0.006): subjects with both neuropathy and claw toe deformity (N+C+) had significantly thicker PA compared with the other three subgroups, being 1.82 mm thicker than N−C+ (p=0.0015), 1.98 mm thicker than N+C− (p=0.0006), and 2.03 mm thicker than N−C− (p=0.0004, Figure 2). PA thickness and IMV were negatively correlated (R^2=0.3233, p<0.001, Figure 3).

Conclusion: Intrinsic muscle atrophy and PA thickening may be related to the development of claw toes. It may be helpful for patients with diabetes to have an active intervention to prevent intrinsic muscle atrophy and PA thickening or to be screened for these changes prior to the development of claw toes.

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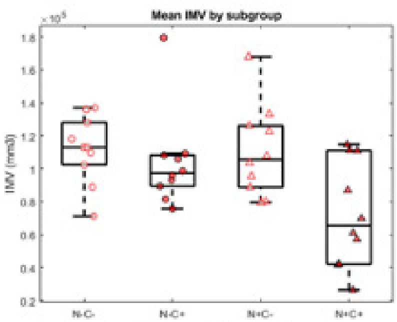

Figure 1. Comparison of intrinsic muscle volume (IMV) between each subgroup.

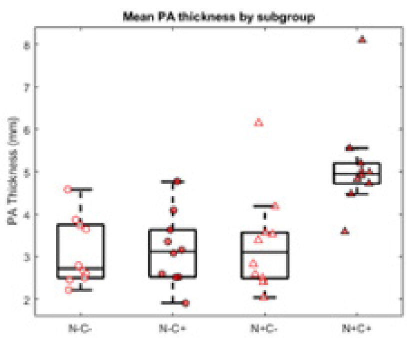

Figure 2. Comparison of PA thickness between each subgroup.

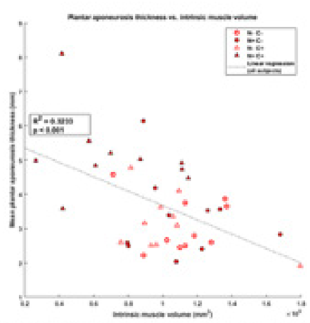
Figure 3. Correlation between plantar aponeurosis thickness and intrinsic muscle volume.

Plantar Irritating Stimuli. Have they the same physiological support?

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Introduction: Plantar foot sole provide enhanced sensory feedback and have been shown to an important participation in the balance function [1-3]. Also, Epine Irritative Plantaire: nociceptive stimuli or plantar irritating stimuli (PIS), is one of feet pathologies, describes in 1945, witch exacerbating reflex mechanisms, increase or maintain an amplification of related influxes perpetuating or amplifying the nociceptive reflex [4-6]. In podiatry, we find 4 PIS types describes: 1) plantar pathologies like metatarsalgies (P [7]); 2) with clinical and stabilometry variation on foam Moliser® by Lepork-Villeneuve (LV, [8]); 3 with Plantar Quotient (PQ) under 100 on Depron® by Foisy-Kapoula (FK, [9, 10]) and 4) with clinical and stabilometry variation on foam Airgom® add to loss of sensori-discrimination by Janin-Dupui (JD, [11, 12]). Currently, we don't know if those 4 PIS types have the same physiological support.
Method: To answer this question, we include 80 subjects with PIS (20 of each type). Their responses were observed through 3 CoP parameters: PQ, speed variation (SV) and sway directional index (DI, [13, 14]) registered by Fusyo® (Medicapteurs, France); randomly on each foam. **Results:** no differences were observed between subject's CoP parameters before stimulation. After stimulation, significant differences were reported into P, LV, FK and JD, with all Cop parameters (table 1).

	PQ < 100 in % of subjects			SV variation in % of subjects			DI varaition in % of subjects		
Foam	Depron®	Moliser®	Airgom®	Depron®	Moliser®	Airgom®	Depron®	Moliser®	Airgom®
P	14	82	78	24	89	83	74	26	24
LV	21	100	47	21	53	37	18	42	31
FK	100	52	39	62	32	25	63	39	27
JD	45	41	100	51	28	100	59	33	72

Table 1: subject's variations are reported in %. PQ: Plantar Quotient. SV: speed variation. DI: sway angle index.

Discussion: Foam decrease the foot afferent cues and induce reduction of the nociception of EIP. Then, the local sensory modulation induce a reorganization of local reflexes: re-emergence of the Aα reflex and underestimation of the C reflex. This process perform all CoP parameters with the specific foam evaluation of each PIS. Their influences on Balance control are depending of foams: The foam induce variation wit variation of 50% between the PIS types: Moliser® induce variation for P but not for FK and JD, also Airgom® induce variation for JD not for FK. Depron® induce QP variation only for FK. Regarding results we can propose that these 4 types of PIS are certainly different because for: FK classifies PIS on only a single subject [10]; LV does not specify the anatomical support advances; JD despite the robust tests used there are still points to clarify. Further studies are needed

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Plantar pressure distribution parameters correlate with physical activity level in menopausal women

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Introduction: The life expectancy rate of women in Brazil [1] leads to longer exposure to health changes in midlife women. Thus, the objectives of this study were: a) to verify if menopausal women present differences in balance and gait compared to younger adult women; b) to verify the relationship between physical activity level and balance and walking in menopausal women. Methods: After screening 48 women volunteered to participate in this study. They were divided into two groups namely a Menopausal Group with age of 55,08 ± 3,46 years old, body mass of 68,27 ± 9,00 kg, body height of 1,61± 0,07 m, body mass index of 26,24 ±3,17 kg/m² and a Young Adult Women Group with age of 23,67 ± 3,06 years old, body mass of 57,94 ± 9,71 kg, body height of 1,62 ± 0,05 m, body mass index of 21,87 ± 2,82 kg/m². Baropodometry (Emed SF-2) was undertaken to evaluate balance (functional reach test) and walking (first step method). Physical activity level was measured by the IPAQ-Short Version. Results: Menopausal women have different balance and walking than those found in younger women (Table 1). Walking velocity measured by baropodometry correlates with the level of physical activity in the menopausal group r=-0,442 (p=0,015). Discussion: Results indicate that menopausal women may experience changes at foot loading patterns that influence their balance and walking and that the level of physical activity may be related to this. These findings contribute to the understanding of factors that may impair the physical health of menopausal women and that interventions may be performed earlier to improve these aspects, promoting better quality of life and preventing development of chronic diseases. Relevance: Clinical plantar pressure measurements regarding fall prevention should be encouraged among midlife women.
Ethical Committee Approval Number: CAE2.950.687
Funding Acknowledgment: This research was supported by a FAPESC Grant

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Table 1: Balance and walking characteristics of menopausal and young adult women

Test	Variable (unit)	Menopausal women (n = 24)	Young Adults Women (n = 24)	P
		±sd or Md (iqr)		
Functional Reach Test –Right Side (cm)		24,58 ± 6,65	30,71 ± 5,32	**0,0005**[a]
Functional Reach Test – Left Side (cm)		22,50 ± 6,22	30,17 ± 5,78	**0,000**[a]
Walking – Right Limb	VMax COP (m/s)	0,908 (0,21)	1,023 (0,31)	**0,008**[b]
	Peak Pressure (kPa)	370,00 (125,00)	455,00 (162,50)	**0,032**[b]
	Time of Peak Pressure (ms)	734,10 (103,45)	662,30 (84,53)	**0,0015**[b]

[a]probability of significance T Test comparison between independente groups; [b]probability of significance UMann- Whitney Test (single-tailed, significance for p<0,05).

Plantar pressure patterns are associated with lower leg complaints in military recruits

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Background: Overuse injuries of the lower extremities frequently occur in both athletes and military recruits. Most studies performed to identify risk factors related to gait biomechanics are cross-sectional, have limited number of subjects and/or are not injury specific. As military recruits have a high incidence of lower leg injuries due to strenuous physical activity in basis training [1], they are a suitable population in which the development of musculoskeletal injuries can be studied in a large population.

Objective: The aim of this study was to identify differences in gait patterns between recruits who develop lower leg complaints and recruits without any complaints during their basis training.

Materials & Methods: 1142 military recruits performed a plantar pressure measurement at the first day and filled out weekly complaint cards during their basic training. Plantar pressure was normalized for total pressure and analyzed at a sensor level using the normalization method developed by Keijsers et al. [1]. Based on the complaint cards, six lower leg complaint groups were studied: anterior, lateral and posterior side of the shank, ankle, heel and knee. Recruits who had complaints at more than one location were excluded from analysis. Recruits without complaints were used as reference group.

Results: Figure 1 shows the mean plantar pressure difference of the six lower leg complaint groups relative to the recruits without complaints. Recruits with lower leg complaints showed a different plantar pressure pattern compared to recruits without any complaints. All complaint groups had increased pressure under the medial forefoot. However, clear differences were visible between the complaint groups.

Discussion: Plantar pressure patterns were associated with lower leg complaints, indicating that gait pattern is a risk factor for the development of lower leg complaints. Furthermore, gait pattern was associated with the location of the complaint. The present study suggest that plantar pressure measurements can be used to identify recruits who are at risk of developing overuse lower leg injuries.

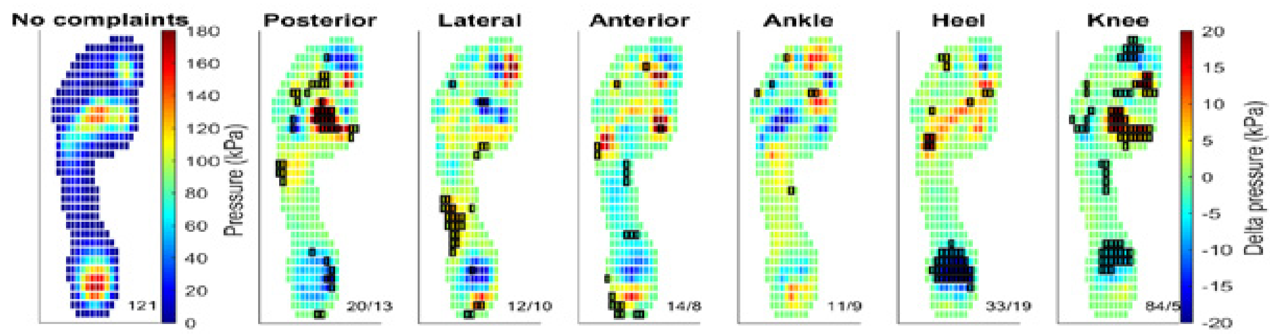

Figure 1. Plantar pressure pattern of recruits without complaints (left panel) Differences in plantar pressure of the recruits with complaints compared to the recruits without complaints. Numbers are number of sides/recruits. Rectangles indicate significant difference pixels.

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Plantar pressure sensors configurations to meet different applications

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Introduction

In footwear or plantar insole assessment, clinical gait analysis, pathologic foot diagnosis and sport training, plantar pressure distributions evaluation has attracted considerable attention [1]. A high spatial and temporal resolution and a fully sensors coverage of the insoles are considered the key requirements in ensuring reliable measures [1-2]. However, there is a growing interest in developing more efficient in-shoe foot plantar sensors, in term of flexibility, mobility and reduced costs [2]. To date, a number of layout was proposed with different sensors size, configuration or technology; some are suitable for specific tasks, some for clinical purposes, some try to reach the best match with other data [1], some are designed for gait phases detection only [2]. Shu et al. [1] reported that the sole of foot can be divided into 15 areas, which support most of the body weight. Therefore, it has been proposed that fifteen sensors are necessary to cover most of the body weight changes [1]. The aim of this study was to simulate different pressure insole layouts, to apply them to a gait analysis dataset and verify the accuracy of the different layouts with respect to the Novel PedarX system [3].

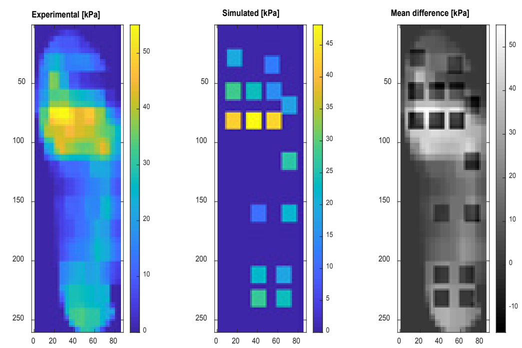

Figure 1: One CS: peak pressure values during the gait cycle.

Methods

Data of 3 cohorts of subjects were acquired with PedarX system (Novel Gmbh): 10 adults (ASs: age 24±3 years, BMI 22.5±2.2 kg/m^2) and 10 children (CSs: age 11.1±2.8 years, BMI 22.8±4.2 kg/m^2) while walking overground, and 7 adults while walking on a treadmill (ASTs, 4 km/h speed, 2% slope) (age 57.9±3.2 years, BMI 23.0±1.6 kg/m^2). Ten gait cycles were extracted from the dataset of each subjects. A code was developed in Matlab (R2016b) to simulate different insole layouts (in term of both sensors size and distribution), by reducing progressively the number of sensors until sixteen [1].

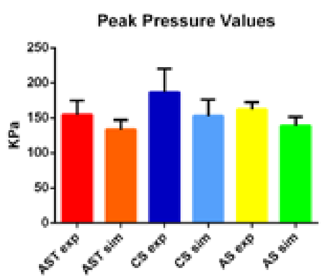

Figure 2: Experimental (exp) and simulated (sim) peak pressure values for each group of subjects.

Results

The 16-sensors configuration (all square sensors, 1.5 cm^2) was chosen as representative of the developed methodology and both the experimental and simulated pressures (peaks for each sensor) were reported in figure 1 and 2, together with the difference between the two measures (frame-by-frame and averaged).

Discussion

A good prediction was obtained on the peak pressures values for AST and AS dataset, while important differences were recorded on the CS dataset. This could be due to the larger variability in foot shapes and gait in the CS group, that can only be accounted for with a larger number of sensors.

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Plantar pressures and adherence in a combination of indoor and regular custom-made footwear for people with diabetes at high risk of foot ulceration

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Background: Adherence to wearing custom-made footwear is a known problem in people with diabetes who are at high ulcer risk, especially indoors. Special indoor footwear that weighs less, is clean and easy to donn and doff might improve adherence, but needs to have similar offloading compared to someone's regular custom-made footwear. The aim of our study was to compare plantar pressures and adherence in a combination of indoor and regular custom-made footwear for people with diabetes at high risk of foot ulceration.

Methods: Custom-made indoor footwear was provided to 35 persons with diabetes, a previous foot ulcer and in possession of regular custom-made footwear. Plantar pressures were measured with Pedar-X (Novel, Munich, Germany), and differences between indoor and regular custom-made footwear compared using paired samples T-tests. Adherence was assessed with the @monitor, both indoors and outdoors, at baseline and one and twelve months after provision of the indoor footwear. Participants were classified as non-adherent when <80% of their steps were made in their prescribed footwear.

Results: 30 participants completed all plantar pressure measurements (mean(SD) age: 70(10) years; females: n=12; type 2 diabetes: n=25; mean(SD) BMI: 30(6) kg/cm^2). Peak plantar pressures of the total foot were 10-13% lower in indoor footwear, while they were similar (0-7% difference) for the different anatomical regions, except the heel (7-10%). In a per-foot analysis, we found total peak pressure <200kPa for 32 indoor shoes (53%) and for 25 regular shoes (42%). Of the 23 patients who were non-adherent at baseline, complete follow-up was available from 14. Mean(SD) adherence increased significantly after provision of indoor footwear from baseline 61(15)% to 78(10)% after one month and 81(16)% after 12 months. This was a result of a significant increase in both indoor adherence (baseline 41(23)% to 71(18)% after one month and 71(25)% after twelve months) and outdoor adherence (baseline 90(11)% to 98(3)% after one month and 98(3)% after twelve months).

Discussion: Custom-made indoor footwear for people with diabetes at high risk of foot ulceration has similar offloading quality compared to their regular custom-made footwear, and it significantly increases adherence in people at high-risk of diabetic foot ulceration who were non-adherent to wearing their prescribed custom-made footwear. From an offloading perspective, it is therefore safe to use the indoor footwear at home. The combination of custom-made indoor and outdoor footwear might reduce the risk of foot ulceration in people with diabetes at high risk.

Plantar soft tissue mechanics is different in diabetes and pre-diabetes and is related to the measures associated with hyperglycemia level

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Background: Glycation that is related to an increased blood sugar level (hyperglycemia) over prolonged periods of time is associated with changes in the plantar soft tissue mechanical properties in Diabetes. Previous studies showed that the plantar soft tissue in people with diabetes (compared to controls with no diabetes) is stiffer. Pre-diabetes (indicated by intermediate hyperglycemia) has implicated to associate with microvascular and cardiovascular complications, while their plantar pressure distribution patterns during walking were found to be similar to the participant with diabetes.

The purpose of this study was to investigate the differences in the mechanical properties of plantar soft tissue between diabetes and pre-diabetes group and establish if those associated with measures related to hyperglycemia level.

Method: Following ethical approval, data was collected from 51 (M/F-21/30) participants with hyperglycemia (Fasting Blood Sugar Level-FBS>100 mg/dL), age >18 years, and no lower limb amputation were recruited. Participants were divided into two groups of age and BMI matched Diabetes (FBS>125mg/dL) and Prediabetes (125mg/dL>FBS>100mg/dL). Shear wave elastography was used to assess the shear wave speed as a measure of soft tissue stiffness at the 1st MTH, 3rd MTH and the heel of participants at both feet, while the participant lying in a supine position.

Results: Mann-Whitney U test indicated a significantly ($P<0.05$) higher shear wave speed in the plantar soft tissue with effect size (r) at the 1st MTH of the left foot at all tested frequencies: r = 0.297 (@450 Hz), r = 0.345 (@500 Hz), r = 0.322 (@550 Hz) and r = 0.275 (@600 Hz); and in the right foot r =0.286 (@400 Hz) in Diabetes as compared to the Prediabetes group. Significant ($p<0.05$) positive correlations were observed between FBS level and the plantar soft tissue shear wave speed at the 1st MTH: rho = 0.402 (@ 400 Hz), rho = 0.373 (@450 Hz), rho = 0.474 (@500 Hz), rho = 0.395 (@550 Hz) and rho = 0.326 (@600 Hz) in the left and rho = 0.364 (@450 Hz) in the right foot.

Conclusion: A higher plantar soft tissue stiffness in diabetes vs prediabetes group can be the result of lower level of glycation in the soft tissue in prediabetes compared to diabetes group. The significant relationship between stiffness of plantar soy tissue and hyperglycemia level can have practical implication in providing foot care in patients with hyperglycemia and be used to assess the severity of foot complications for patient stratification.

Plantar stimulations could induce heterophoria and also could reduce this eye misalignment.

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Introduction: Lateral Arch Stimulation (LAS) induce hetreophoria [1]. Vertical Heterophoria (VH) is a common phenomenon in neurodevelopmental disorders [2, 3], Proprioceptive Dysfunction Syndrome (PDS) [4], Dyslexia (DL) [5] and Sensory Processing Disorders like dyspraxia (DP) [6, 7]. All expose a poor integration of proprioceptive information which plays an important role in the dysfunction of these children. When dysproprioception is reduce VH is reduced, come back to the Vertical Orthophoria (VO), and Dyslexia was improved [4, 5]. It is possible to counter this dysfunction by changing the plantar information through plantar insoles (PI) and then Dyslexia and Dyspraxia could be reduce [8, 9].
Given the presence of VH described in neurodevelopmental disorders, it seems logical to investigate whether LAS and PI could induce/reduce VH and then increase VO.

Method: 5 groups PDS, DP, DL, typical neurodevelopemental children without VH (TO) and with VH (TH) with is present in 20% of the general population with no specific clinical signs [4, 5] of 30 children each (0<FPI<5). VH/VO are report with Maddox rod [4, 5, 10, 11]. Thinness of LAS was 3 mm [1] and PI are realized after podiatry examen and stimulations were between 3-7 mm [12-14].

Results numbers of children with VH are exposed in table 1 in significance of stimulations. Controls expose the number of VH in each group. **Discussion:** In each groups, VH are reduce by plantar stimulation with increase number for PI than LAS. In reverse LAS induce more VH than PI in for typical children (without VH). Lower numbers of VH would expose effects of sensori-integration and a significant competency of plantar stimulations. Also, PI reduces more eye misalignment than LAS but all induce eye misalignment when children present Orthophoria. Consequently score variations could first complete the result of LAS [1] with carefully attention to used its and in second and those indicate that in neurodevelopmental disorders PI could reduce eye misalignments. This must be evaluated to improve the podiatry therapeutic proposition and it pluridiciplinarity participation. However, this framework needs to be validated in clinical trials. Significance/Clinical relevance: Improvement of the podiatrist clinical practice in neurodevelopmental disorders, Proprioceptive Dysfunction Syndrome and Sensory Processing Disorders.

	Number of VH		
	Control	LAS	PI
PSD	30	30	24
DL	30	30	21
DP	30	30	19
TO	0	5	2
TH	30	30	18

Legend of table 1: Number of VH induces by stimulations depending of the children group.
PSD: Proprioceptive Dysfunction Syndrome.
DL: Dyslexia.
DP: Dyspraxia.
TO: Typical Children with Orthophoria.
TH: Typical Children with Heterophophoria
LAS: Lateral Arch Stimulation.
PI: Plantar Insoles.

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Posterior and Middle Facets of the Subtalar Joint: The Retrospective Search for an Early Sign of Peritalar Subluxation and Progressive Flatfoot Deformity

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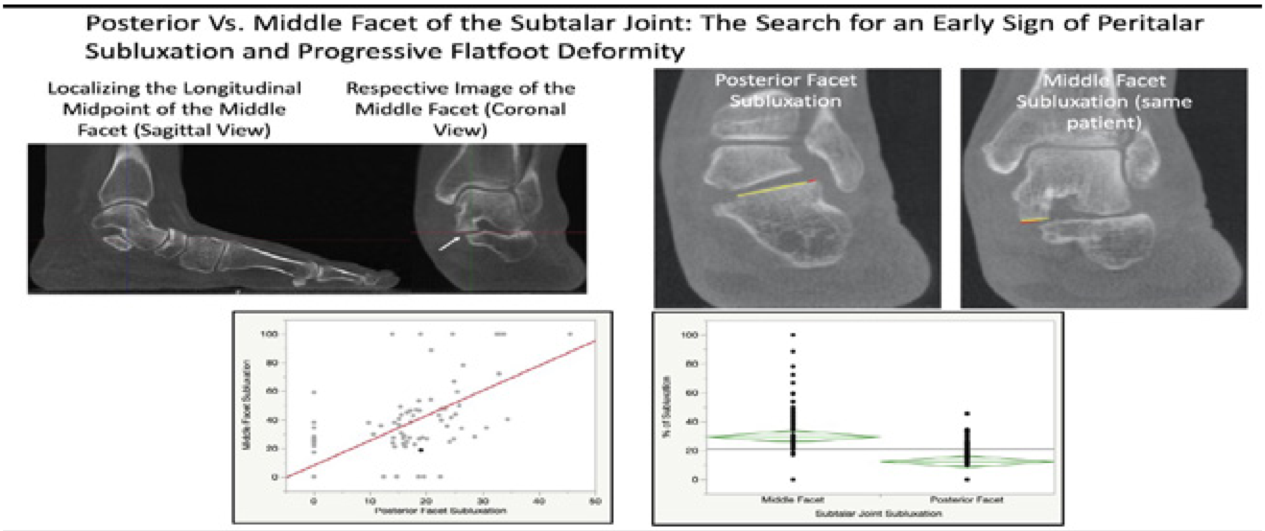
Introduction: Adult acquired flatfoot deformity (AAFD) is a complex three-dimensional (3D) pathology characterized by peritalar subluxation (PTS) of the hindfoot. The objective of this study was to compare the amount of subluxation between the middle and posterior facets in patients with AAFD [1,2,3].

Methods: In this IRB-approved retrospective comparative study, seventy-six AAFD patients (87 feet) who underwent weightbearing CT (WBCT) were included. Two blinded Fellowship-Trained Orthopedic Foot and Ankle Surgeons with >10 years of experience measured subtalar joint subluxation at the posterior and middle facets as well as the Foot and Ankle Offset (FAO). Intra- and interobserver agreement was measured for PTS measurements using intraclass correlation coefficient (ICC). Inter-method agreement was assessed using Spearman's Correlation and Bivariate Analysis. Paired comparison was performed using Wilcoxon. A multivariate analysis and a partition prediction model were used to assess influence of PTS measurements on FAO values. P-values of <0.05 were considered significant.

Results: ICC for intra- and interobserver reliabilities were respectively 0.97 and 0.93 for posterior, and 0.99 and 0.97 for middle facet subluxation. The inter-method Spearman's correlation between subluxation of posterior and middle facets was measured at 0.61. In a bivariate analysis, both measurements were found to be significantly and linearly correlated ($P<0.0001$; $R^2=0.42$). Measurements of middle facet subluxation were found to be significantly higher than the posterior facet subluxation, with a median difference (using Hodges-Lehman factor) of 17.7% ($p<0.001$; 95% CI, 10.9 to 23.6%). We also found that for every 1% increase in posterior facet subluxation there was a corresponding 1.6-fold increase in middle facet subluxation. Only middle facet subluxation measurements were found to significantly influence FAO calculations ($p=0.003$). The partition prediction model demonstrated that a middle facet subluxation value of 43.8% represented an important threshold for increased FAO (Figure).



Conclusion: This study is the first to compare WBCT measurements of subtalar joint subluxation at the posterior and middle facets as markers of PTS in patients with AAFD. We found a positive linear correlation between the measurements with subluxation of the middle facet being significantly more pronounced than that of the posterior facet by an average of almost 18%. This suggests that middle facet subluxation may provide earlier and more pronounced marker of progressive PTS in patients with AAFD.

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Prescribing custom dynamic orthoses to reduce risk of post-traumatic OA after tibial pilon fractures

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Introduction: Surgical fracture reduction is the mainstay of tibial pilon fracture treatment, but despite best efforts, elevated contact stress from residual incongruity increases the risk of post-traumatic osteoarthritis (PTOA). Recent advances in ankle custom dynamic orthoses (CDOs) provide a complementary treatment that can improve function and reduce pain after limb trauma.[1] These devices include design elements that can be varied to influence forces and motions in the limb,[2] which in turn can decrease load transfer across the ankle.[3] This study investigated whether external bracing support can reduce contact stress exposure after treatment of tibial pilon fracture.

Methods: A generic musculoskeletal model was scaled in OpenSim [4] to match the weight of 17 patients who had operatively treated tibial pilon fractures. Generic motion data were applied to body-weight-scaled models to generate ankle kinematics and compute associated muscle control forces. A torque actuator (stiffnesses of 2.5 or 6 Nm/rad/kg) was added to the model to represent a CDO. Resulting ankle kinematics were used as inputs to a discrete element analysis (DEA) patient anatomy-specific model of the ankle to compute contact stress over-exposures on the distal tibia articular surface.[5]

Results: Adding a CDO substantially altered OpenSim-computed ankle kinematics (Fig. 1). The maximum dorsiflexion angles were 2.3° and 0.8° for CDO stiffnesses of 2.5 and 6 Nm/rad/kg, respectively. DEA-computed contact stress distributions were split into 9 distinct, clinically relevant regions for analysis of CDO influence upon joint contact stress. Each CDO design caused a reduction in contact stress exposure on the tibial articular surface (Fig. 2); regionally-averaged exposures for the 6 Nm/rad/kg trial were reduced as much as 16% in the middle of the joint and on the order of 5 to 10% elsewhere.

Discussion: These promising results suggest that a CDO can relieve harmful contact stress exposure and PTOA risk by favorably altering gait kinematics/kinetics. This potential benefit is separate from any limb offloading provided by the CDO cuff. The modeling system developed will undergo validation as part of the ongoing project. Future work will incorporate direct offloading of the ankle joint and consider motor control alterations associated with the CDO.

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Figure 1. Plot of ankle angle across scaled models during stance phase of gait with and without a CDO, from heel strike to toe off.

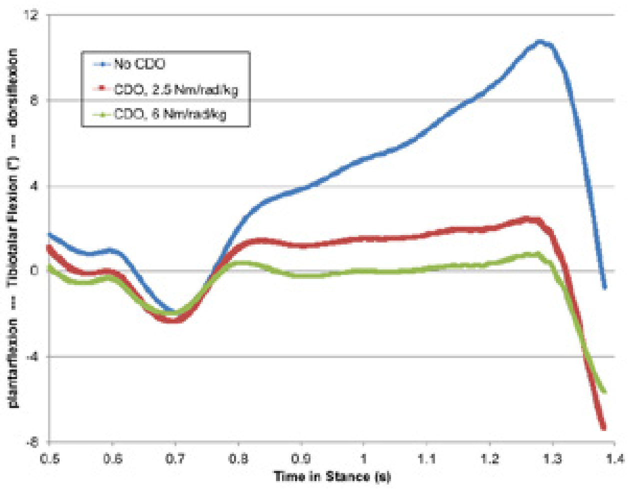
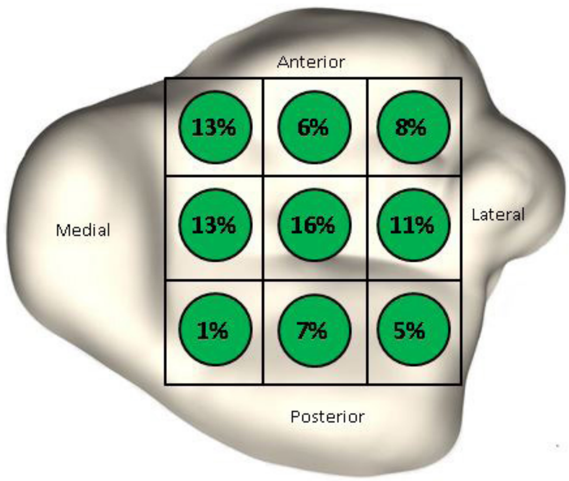


Figure 2. Percent reduction of regional contact stress exposure on the tibial articular surface, using OpenSim generated loading patterns without an CDO compared to with an CDO with 6 Nm/rad/kg of torsional stiffness.



Propulsion patterns during habitual walking gait: do 'high gear' and 'low gear' gait exist?

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Background: 'High gear' and 'low gear' are terms used clinically to describe propulsion patterns during walking. Initially proposed by Bojsen-Møller in 1978, the evidence to support this theory is limited. However, over the years, clinicians have casually been using these terminology to describe propulsion patterns to patients and oftentimes associate 'high gear' with being an effective way of propulsion and 'low gear' as a less effective way of propulsion. In addition, the effectiveness of walking had been previously associated with the speed of propulsion. This pilot study aims to provide an insight into propulsion patterns observed during habitual walking of healthy population and whether these propulsion patterns could be associated with 'high gear' and 'low gear' descriptions.

Methods: 23 healthy participants, aged between 19-64 with a Foot Posture Index (FPI) score between 0 and +7, walked habitually to their comfortable walking speed for a minimum of 30 metres with the wireless F-scan in-shoe pressure sensor system (Tekscan) fitted in identical control shoes. Average peak plantar pressures, centre of pressure velocity, and locations of the centre of pressure (CoP) in the forefoot were obtained. The CoP locations were further categorised and compared to the 'high gear' and 'low gear' propulsion patterns as described by Bojsen-Møller.

Results: A total of 10 propulsive patterns were found and categorised into 3 types of gears associated with Bojsen-Møller's proposal: 1 pattern of 'high gear' (transverse axis), 5 patterns of 'low gear' (oblique axis), and 4 patterns of both gears. There is also no apparent relationship between propulsion patterns and the centre of pressure velocity.

Conclusion: Propulsive patterns found in the sample population are hugely varied. Even within the same participant, their left and right feet could demonstrate different propulsion patterns. Although the patterns could be associated with 'high gear' and 'low gear' descriptions, the terms are probably too over-simplified to have meaningful use in clinical practice.

Figure 1. A plantar foot pressure example demonstrating locations of the centre of pressure in the forefoot, and the categorisation of propulsion patterns. The order of the letters signifies the direction of movement of the centre of pressure during propulsion.

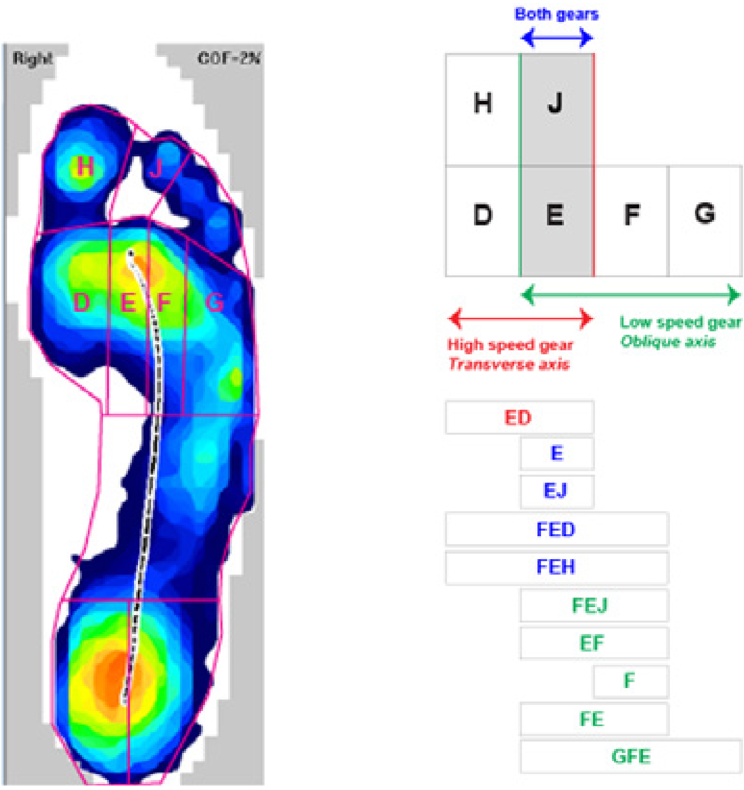
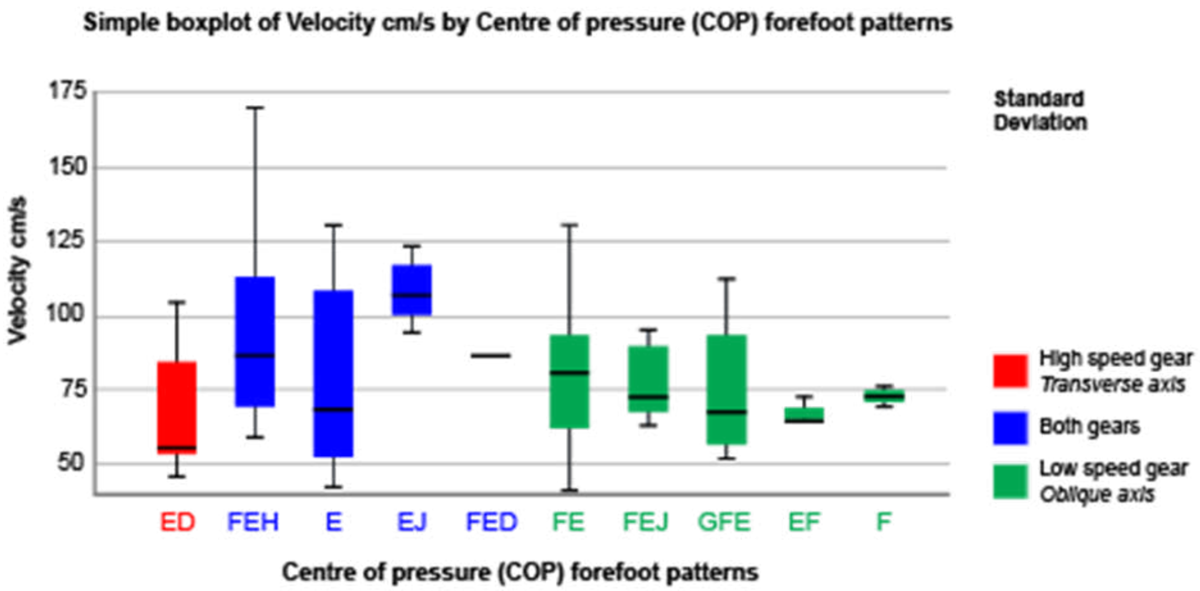


Figure 2. Centre of pressure velocity associated with different propulsion patterns.



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Publication trends of research on hallux valgus (1998 - 2018): A bibliometric study

Introduction/Purpose: Hallux valgus (HV) is a very common deformity among the affections of the foot and the interest in the subject is always present in the daily routine of orthopedic surgeons. We investigated the trend of HV publication in literature.

Methods: The research was carried out by searching the Web of Science database between 1998 - 2018, analyzed through bibliometric methodology. We used the "Bibliometrix" package for software R in data compilation and VOSviewer for graphic creation.

Results: In total, 547 indexed studies were selected between 1998 and 2018 in WoSCC. The distribution of publications between the years is shown in Figure 2, with an increase in the number of publications between 1998 and 2018, evolutionarily proportional over the years (r^2 = 0.9083). In addition, temporal analyzes indicate that the field as a whole has become more productive over time, with an annual percentage growth rate of 12.43%. For the countries with the largest number of publications, the United States had the highest number of articles (n = 168). The analysis of the countries with the greatest presence in the world literature published on the subject of HV was also evaluated through the number of citations, the United States with the highest number of citations (n = 2,342). The search found 20 journals but those that presented the most relevance of articles were Foot & Ankle International (35.28%). The author with the highest scientific productivity in the HV area was Coughlin M.J. with 17 published studies. The total number of authors in the articles included in the bibliometric evaluation was 2,333, with a mean of 4.26 authors per article.

Conclusion: The number of published studies on hallux valgus has been growing rapidly since 2012. The United States has the leading position in global research. The journal with more articles was Foot and Ankle International, with Coughlin M.J. being the most representative author.

LEVEL OF EVIDENCE: Level I: High-quality prospective randomized clinical trial

Key-words: Hallux Valgus; Bibliometrics; Forefoot, Human

Quantitative analysis of talar dome morphology

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Introduction: A flat-top talar dome deformity can alter ankle mechanics and impact daily activities. Radiographic determination of flatness is difficult using traditional measures. The purpose of this study is to describe a new method to quantify the talar dome morphology using lateral radiographs and a custom-written image processing algorithm.

Methods: Skeletally mature patients previously treated for idiopathic clubfeet were identified from our institution's clubfoot registry. Plain weight bearing lateral foot films were obtained in all patients. Radius of curvature (ROC) of the talar dome was measured along with length and height of the talus, alpha angle and radius of the tibial plafond. The ratio of the radii of the talar dome and tibial plafond (R/R Ratio) was also determined. Custom-written, image processing MATLAB code was used to identify the talus from the lateral radiograph. Following manual identification of the articulating surface, the average slope of the anterior/central/posterior regions of the talar dome were calculated. Talar dome flatness was determined as the variance in the estimated slopes across all three regions. Higher variance indicated a more normal talar dome morphology, with lower variance indicating a flatter dome. Inter-rater reliability of typical radiographic measures (4 raters) and the MATLAB based talar dome flatness measure (3 raters) were determined. Spearman's rho was used to determine correlations between traditional radiographic and MATLAB flatness measures.

Results: For radiographic measures, the Inter-rater reliability (IRR) was determined for 52 feet. IRR was near perfect for the ROC of the talar dome (ICC=.985), talar length (ICC=.952), R/L ratio (ICC=.987), and alpha angle (ICC=.928). Measurement of the radius of the tibial plafond (ICC=.827) and talar height (ICC=.893) were reproduced with excellent reliability. The IRR of the R/R ratio was moderate (ICC=.608).

Preliminary IRR for the MATLAB-based talar dome flatness (15 feet) was excellent (ICC=0.895). Flatness was strongly correlated with ROC of the talar dome (r=.621, p=.013), alpha angle (r=.557, p=.031) and R/R Ratio (r=-.589, p=.021)

Discussion: Flatness of the talar dome can be difficult to describe, as there lacks a single measure to accurately define its morphology. The method developed in this study was quick to apply (less than 5 to 10mins per foot) and had high inter-rater reliability.

Relevance: A new image-processing based definition of flatness was developed using the varying regional slopes of the talar dome. This new method is easy and quick to apply and showed strong correlation to traditional measures of talar dome morphology.

REARFOOT KINEMATICS OF BAREFOOT AND SHOD CONDITIONS IN RECREATIONAL RUNNERS

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Introduction: Currently, race is the most popular physical activity and causes a high number of injuries in their practitioners [1]. The footwear companies invest in several types of shoes that aim to adjust or maintain the kinematic of the foot. However, the influence of runner's footwear of choice on the rearfoot movement or alignment of this complex movement is still controversial. Therefore, this study investigated the eversion angle (EA) during barefoot and shod running of runner's footwear of choice. Methods: This was a cross-sectional study with 111 recreational runners (81 men and 30 women) aged 38.6 ± 9.7 years (74.9 ± 12.0kg, 1.74 ± 0.08 cm), who ran an average of 3.4 ± 1.0 times a week and 31.8± 16.6km a week, and could comfortably run at 10km/h on a treadmill ergometer. The kinematics was assessed with participants running barefoot and shod on a treadmill ergometer (HPX 40, Total Health, Brazil) surrounded by 6 infrared cameras at 120Hz (Vicon Motion System Ltd., Oxford Metrics, UK) at self-selected speed in both conditions (mean speed 9.86km/h [95%CI: 9.75 to 9.96]). The EA was defined by the intersection between two straight lines passing through the four markers placed on each lower extremity [2]. The marker positions and EA were analyzed in Visual 3D software (C-Motion, USA). The kinematic data was processed based on residual analysis on kinematic data using a zero-lag, digital fifth order, butterworth filter, low-pass filter with cutoff frequency of 6 Hz. The EA classification was 0 to 7 excessive supination (underpronation), 8 to 15 degrees as neutral (normal), and values greater than 15 degrees as excessive pronation (overpronation). Result: Runners classificated as feet neutral showed increase in EA in shod condition (11,81±2,10°) when compared with barefoot condition (10,10±1,98°) (p<0,00), while the runner´s classified as supinated (5,12±3,35°) and pronated (16,67±0,98°) did not show a statistically significant difference in EA (overpronation: 18,36± 1,98; p=0,22; supination: 5,66± 4,54; p=0,74). Conclusion: The eversion angle increased during shod running when compare with barefoot running. This may justify the need to wear shoes that mimic the EA or maintain the dynamic alignment of the rearfoot.

Trial registration

Ethics committee: **CAAE:** 41171215.7.0000.0065

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Redefining the juvenile bunion

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Introduction: The purpose of this study is to characterize the radiographic parameters that constitute the juvenile bunion and determine which parameters correlate with greater symptomatology.

Methods: A retrospective analysis of prospectively enrolled patients between 10 and 18 years of age with idiopathic bunion deformities was performed at a single pediatric institution over a two-year period. Standardized weight-bearing radiographs were used to determine the hallux valgus angle (HVA), intermetatarsal angle (IMA), distal metatarsal articular angle (DMAA), hallux interphalangeus angle, metatarsal cuneiform angle, cuneiform obliquity, sesamoid position (SP), and joint congruency. Foot specific patient reported outcome (PRO) measures were administered at initial presentation. Patients also underwent dynamic plantar pressure analysis to determine peak pressure (PP), contact area (CA), contact time and pressure-time integral (PTI) within each of 11 plantar regions. Bivariate analysis was used to determine the association between individual deformity parameters and the relationship of those parameters to PRO's and pressure variables.

Results: 32 patients (57 feet) met inclusion criteria (average age 14years). 48/57 feet (84%) had an elevated DMAA (average 23.1°±7.8°). The DMAA correlated positively with the HVA ($r = 0.734$, $p<0.001$), IMA ($r = 0.439$, $p=0.001$), and SP ($r=0.627$, $p<0.001$). No correlations were identified between deformity parameters and age, gender or BMI percentile. While patients with a greater DMAA and more lateralized SP reported greater functional limitations based on the Oxford Foot and Ankle Questionnaire, Foot and Ankle Ability Measure, and Foot and Ankle Outcome Score (FAOS) sub-scores, those with a higher IMA reported more pain on the FAOS pain sub-score ($r = 0.354$, $p=0.014$). Multivariate analysis revealed that the IMA remained significantly associated with pain after controlling for other deformity and demographic parameters ($p=0.024$). Pressure analysis revealed that the HVA correlated with increased PP ($r = 0.663$, $p=0.001$) and PTI ($r = 0.604$, $p=0.002$). The 2nd metatarsal PP and PTI correlated with lower PRO scores and increased pain-related disability. Conversely, increased 1st and 5th metatarsal contact area correlated with improved PRO scores.

Conclusion: Unlike the average adult bunion, the vast majority of juvenile bunions demonstrate elevation of the DMAA which correlates significantly with deformity parameters such as HVA, IMA, and SP. While a higher DMAA and lateralized SP are associated with greater functional disability, IMA elevation, perhaps due to a shift in plantar pressure distribution to the 2nd metatarsal, seems to correlate with complaints of pain.

Significance: Understanding this unique deformity may allow for improvement upon the historically poorer results following operative management.

Reduced ankle dorsiflexion range of motion is related to increase ankle plantar flexion internal moment during gait

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Introduction

The ankle joint is responsible for two-thirds of the energy generated during the push-off phase of the gait [1]. Most of the ankle impulse during gait is due to the release of elastic energy by the calcaneal tendon, resulting from the stretching of this tendon during ankle dorsiflexion occurring at the single support phase [1]. Therefore, walking with reduced ankle dorsiflexion range of motion (ADF-ROM) may affect the ability of the ankle joint to produce the required moment during walking. Thus, the present study aimed to investigate the relationship between the ADF ROM and ankle internal moment during gait.

Methods

Sample: A convenience sample of 39 healthy individuals (16 men and 23 women) participated in this cross-sectional observational study (CAAE 84029718.6.0000.5149).

Inclusion criteria: (1) age between 19 and 44 years old; (2) no injury or surgery in the lower limbs or pelvis in the last six months; (3) shank-forefoot alignment angle smaller than 14°; (4) hip internal and external rotation ROM between 34 and 71°, and 25 and 56°, respectively, for women, and between 23 and 53°, and 29 and 56°, respectively, for men.
Exclusion criteria: Complaints of pain or discomfort during data collection.

Procedures: Clinical ADF-ROM was assessed using a goniometer, with the participant in prone with the knee extended. Kinetic data during self-selected walking speed were collected with a tridimensional motion analysis system.

Data reduction: Kinetic data of the dominant lower limb were analyzed. The ankle plantar flexion internal moment peak was analyzed.

Figure 1: Scatter Plots of ankle plantar flexor internal moment peak (Nm/Kg (y-axis) versus the Ankle Dorsiflexion Range of Motion (ADF-ROM) angle ((x-axis) of correlations during gait. PF – Plantar Flexor; ROM – range of motion.

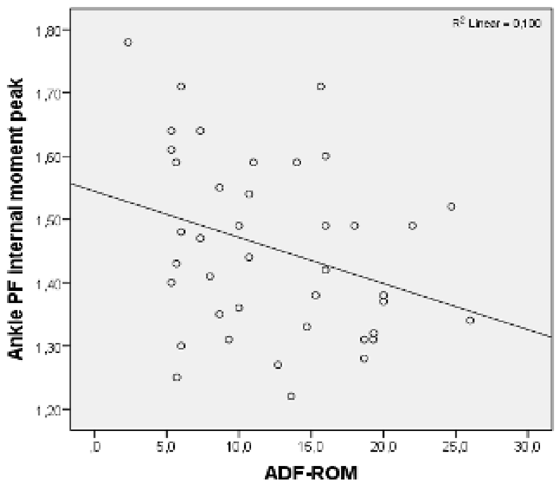
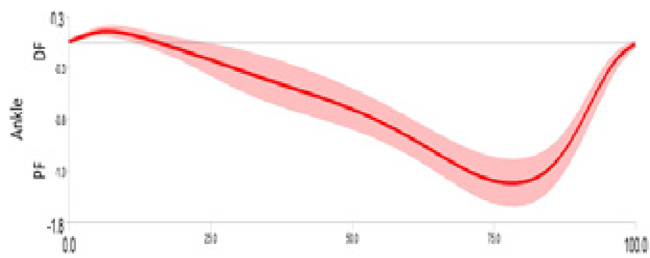


Figure 1: Internal moment curves of significant variables during the stance phase in normal gait. PF – plantar flexor.



Data analysis: Pearson correlation coefficients were used to test associations between ADF-ROM and kinetic variables, considering $\alpha = 0.05$.

Results
Participants presented clinical ADF-ROM between 2.3° to 26°. Reduced ADF-ROM was associated with increasing ankle plantar flexor internal moment peak during the push-off phase of gait (Figures 1 and 2).

Conclusions
Reduced ADF-ROM may limit the anterior translation of the tibia, storing less energy in the calcaneal tendon during the gait single support phases and, consequently, requiring a greater amount of energy production at the ankle [2]. Therefore, to compensate the smaller elastic energy stored due to the limitation of the tibia anterior roll, the ankle may increase its plantar flexion internal moment peak during push-off to keep the gait speed [3].

Acknowledgments
CAPES, FAPEMIG, and CNPq.

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Relationship between Achilles tendon properties, metabolic cost and 3000 m running performance

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Introduction: Tendons play a fundamental role in storing and releasing elastic energy, minimizing metabolic cost (C_{MET}) in distance running. This behavior is related to the tendon's ability to resist deformation (e.g. stiffness), which is controlled by changes in the tendon morphological [cross-sectional area (CSA)], and material (e.g. Young's modulus) properties [1]. However, the relationship between Achilles tendon properties, C_{MET}, and running performance are still uncertain. This study aimed to correlate the Achilles tendon properties, C_{MET} and 3000m running performance. **Methods:** 7 trained male long-distance runners (31 ± 8 years) participated in this study (Ethics Committee approval number: 2.437.616). Ultrasound was used to determine the Achilles tendon CSA, length, and elongation as a function of plantar flexion torque during voluntary plantar flexion. Tendon force-elongation and *stress-strain* relationships were determined by maximum voluntary isometric contractions on a dynamometer. Then, C_{MET} was measured in the running economy test (5min) at 12 and 16km.h^{-1} on a treadmill. After 10 minutes at rest, the 3000m running performance test (athletics track) was performed. VO_2 was measured by spirometry. Correlations between Achilles tendon properties, C_{MET} (12-16km.h^{-1}), and 3000m running performance were obtained through Person's test ($p<0.05$). Correlation coefficient was classified as null (0), low (0-0.3), moderate (0.3-0.6), high (0.6-0.9), very high (0.9-1), and perfect (1). **Results:** C_{MET} at 16km.h^{-1} showed high correlation with CSA (r=-0.834, p=0.02), and Young's modulus (r=0.880, p=0.009). No correlation was found with tendon stiffness, tendon length, C_{MET} at 12 km.h^{-1} and 3000m running performance. **Discussion:** C_{MET} is correlated with CSA and Young's modulus only at 16km.h^{-1}. Above 14km.h^{-1} the muscle presents an optimal activation (isometrically) and the stretching and shortening are determined by tendons with less energy expenditure [2]. **Relevance:** A greater Achilles tendon CSA can reduce tendon *stress* at the same absolute force and same *strain*. Thus, a higher CSA could be associated with a possible improvement of the capability to store and release elastic energy [3] resulting in an increase in metabolic economy. Therefore, long-distance runners may achieve a lower C_{MET} at 16km.h^{-1} by tendon hypertrophy and greater tendon work. Besides that, our results show a correlation between Young's modulus and C_{MET}, showing that the material properties, main responsible for tendon mechanical adaptations [4], can influence positively the C_{MET}.

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Relationship between ankle torque and clinical balance test in elderly

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Background: The aging process promotes a decline in postural control and muscle function. Moreover, aging process can bring changes in postural strategies, with greater dependence on ankle strategy for balance control [1]. The weakness of the ankle joint muscles can promote a postural instability in elderly and it can be related to fall risk. Balance scales that assess static and dynamic balance are essential in clinical practice. However, the relationship between balance clinical test and muscle torque in ankle joint is not totally clear. Thus, the aim of this study was to investigate the relationship between ankle torque and clinical balance test in elderly. **Methods:** Sixty-one older adults (65.9±4.4 years; 1.6±0.05 m; 67.3±10 kg) participated in this study. All participants had no musculoskeletal or neurological disorder that would affect task performance. The local ethics committee approved all procedures (number: 2.061.608), and participants signed an informed consent form before starting the experiment. An isokinetic dynamometer (Biodex System) was used to assess the muscle function of ankle joint. The movements of ankle (dorsiflexion and plantar flexion) were evaluated. The evaluation consisted of isokinetic tests in concentric mode with sequence of velocities and predetermined of 60°/s (5 trials) and 120°/s (10 trials) for both limbs. Pear torque at 60°/s and mean power at 120°/s were calculated. The sum of peak torque and mean power of both ankle (right and left) was calculated [2]. Balance control of older adults was investigated using a clinical balance assessment total, MiniBestest [1], a clinical assessment tool that aims to analyzed different balance control systems (biomechanical constraints, stability limits/verticality, anticipatory postural adjustments, postural responses, sensory orientation and stability in gait). The Pearson correlation was used to verify the relationship between muscle function variables (total peak torque and total mean power) and clinical balance control (MiniBESTest score) ($p \leq 0.05$). **Results:** Total peak torque and total mean power for both movements of the ankle (dorsiflexion and plantar flexion) showed a positive association with MiniBESTest score (Table 1). **Conclusion:** Based on the results, this relationship indicates that ankle torque production can contribute for balance control. Moreover, these results reinforce the inclusion of ankle muscle strength in physical activities for elderly that can contribute to reduce fall risk in elderly population. For future studies, it is recommend analyzing the association of each item of the balance control scale with different lower limb joints.

Table 1: Pearson Correlation between total peak torque (TPT), total mean power (TMP) for dorsiflexion and plantar flexion movements and MiniBESTest score.

Pearson Correlation	MiniBEST score
TPT 60°/s Plantar Flexion	r=0.4, p≤0.001*
TMP 120°/s Plantar Flexion	r=0.5, p≤0.001*
TPT 60°/s Dorsiflexion	r=0.3, p=0.04*
TMP 120°/s Dorsiflexion	r=0.4, p=0.003*

*p≤ 0.05

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Reliability in ultrasound measurements of plantar aponeurosis thickness

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Purpose: Given the increasing research interest in ultrasound plantar aponeurosis (PA) thickness measurements, we aimed to analyze the inter and intra-rater reliability of independent sonograms and to identify the error related to the image analysis procedure.
Methods: Twenty-one healthy men participated in this study. Imaging of PA consisted of two independent sonograms per subject. Two raters (R1 and R2) evaluated each sonogram twice using standardized steps. Precision of the image analysis procedure was analyzed using the Bland and Altman plot and Intraclass Correlation Coefficient (ICC). Agreement estimates and ICC were used to assess absolute and relative inter and intra-rater reliability.
Results: Reliability of PA thickness was found to depend strongly on the number of images acquired per subject. Intra-rater agreement for single measurements were 0.696 (R1) and 0.495 (R2), whereas average measurements yielded values of 0.821 (R1) and 0.662 (R2), respectively. Precision within a sonogram varied from ICC values of 0.873 to 0.960 (intra-rater) and 0.670 to 0.822 (inter-rater) (Table 1).
Conclusion: Most part of the error in PA thickness measurements seems to be related to the sonogram acquisition process and not to the visual inspection of the image. To minimize error, average values of a minimum of two images per subject should be used. The moderate agreement between raters found in this study ratifies the need of all measurements being made by the same rater or group of raters. If a single rater evaluates all subjects, performing multiple measurements over one image does not seem to affect intraclass correlation coefficient as much as acquiring multiple images.

Table 1. Mean ± standard deviation of plantar aponeurosis thickness for two independent measurements/sonograms (Image 1 and Image 2) and two raters (Rater 1 and Rater 2). Intra-rater and inter-rater agreement were assessed using ICC, SEM and MDC estimates.

		Plantar aponeuroses thickness (cm)		**ICC* (SEM/ MDC)**	
		Image 1	Image 2	Single	Average
Rater 1		0.22 ± 0.04	0.21 ± 0.04	0.696 (0.02/ 0.07)	0.821 (0.02/ 0.05)
Rater 2		0.24 ± 0.05	0.23 ± 0.04	0.495 (0.04/ 0.12)	0.662 (0.03/ 0.10)
ICC** (SEM / MDC)	Single	0.698 (0.02/ 0.07)	0.670 (0.02/ 0.06)	-	-
	Average	0.822 (0.02/ 0.05)	0.803 (0.02/ 0.05)	-	-

ICC: Intraclass Correlation Coefficient
SEM: Standard error of measure (cm)
MDC: Minimal detectable change (cm)
*intra-rater reliability (ICC [3,1-2] agreement) between independent images (Image 1 and Image 2)
** inter-rater reliability (Rater 1 and Rater 2) (ICC [3,1-2] agreement) for each Image.

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Reliability of Inertial Measurement Unit in Determining Maximum Ankle Dorsiflexion Angle at Terminal Stance

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INTRODUCTION: In a physical therapy clinic, range of motion (ROM) is typically measured statically. The most accurate way to analyze dynamic ROM is through motion capture [5]. However, these systems are costly and time consuming making them ill-suited for clinical use. Inertial measurement units (IMUs) allow ROM measurements of dynamic activities in the clinical setting [1,4]. The purpose of this study was to determine the test-retest and between-day reliability of using IMUs to evaluate the ankle dorsiflexion during gait.

METHODS: Five healthy adults (4M, 1F, Table 1) performed two (T1,T2) 10 m walk tests during each evaluation, each consisting of three trials, separated by five minutes. This was repeated two weeks later (D1,D2). Using MuscleLab® (Ergotest Technology, Oslo, Norway) measurement system, four IMUs were attached to the participants' feet and shanks to measure gait spatiotemporal parameters [2] and tibia tilt angles [3] during walking. Gait speed was calculated using timing gates. All subjects wore standardized shoes. Analysis of gait and maximum tibia tilt angle (MTTA) at terminal stance were performed using MuscleLab® (Table 2). The evaluation and processing were performed by one rater. Using inter-class correlation coefficient (ICC), an average of three gait cycles between trials one and two and an average of nine gait cycles between test occasion one and two were used to determine test-retest and between-day reliability, respectively.

Table 1. Demographics

	Age (yrs)	Height (cm)	Weight (kg)	BMI (kg/m^2)
Average	28.8	176.3	72.1	23.2
STD	7.6	13.0	9.4	0.8

Table 2. Gait Spatiotemporal Parameters

	Gait Speed (m/s)	Stance Phase L/R (%)	Swing Phase L/R (%)	MTTA T1 L/R (°)	MTTA T2 L/R (°)	MTTA D1 L/R (°)	MTTA D2 L/R (°)
Average	1.4	61.1/61.2	38.8/38.9	11.7/14.8	12.7/13.1	12.0/13.6	13.7/13.4
STD	0.2	1.1/1.7	1.7/1.1	5.2/6.3	4.8/4.4	5.0/5.2	4.1/5.9

RESULTS: Test-retest ($ICC_{3,3}$=0.916, 95%CI=0.660–0.979; SEM=1.17°) and between-days ($ICC_{3,9}$=0.911, 95%CI=0.656–0.978; SEM=1.2°) reliability were excellent for tibia angle.

DISCUSSION: IMUs were found to be reliable and valid for determining dynamic ankle dorsiflexion ROM. This is significant because of the time saved in and the ability to measure dynamic ankle ROM during a clinical evaluation.

RELEVANCE: IMUs are a reliable technology to use in the clinic to determine a patient's maximum weight bearing dorsiflexion angle during midstance. This information will be useful to assess gait in patients with foot, ankle, and lower leg injuries. Furthermore, the results of the gait analysis can be used in determining an effective plan of care.

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Searching an alternative to the triple arthrodesis for flatfoot deformity correction: A finite element analysis.

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Introduction: Triple arthrodesis is one of the most common procedures used to correct the flatfoot deformity in stage III (rigid deformity) [1, 2]. This highly restrictive procedure fuses the midfoot joints, blocking the foot arch lengthening and reducing the foot abduction. Many podiatric surgeons consider triple arthrodesis as the gold standard for flatfoot correction. However, some recent studies have shown some long-term side effects related to this procedure, being the toes pain and walking instability the most common [2]. An alternative used by some surgeons is to correct the foot deformity, but using some less restrictive surgical procedures, such as isolated midfoot arthrodesis or medializing calcaneal osteotomy (OMC). Recent studies show that isolated talonavicular arthrodesis could reduce the forefoot pronation [3]; while the OMC reduce the first metatarsal load, forcing a varus movement in the hindfoot [2]. The objective of this study was to evaluate both the biomechanical stress changes in the forefoot, and the structural correction caused by OMC, the talonavicular arthrodesis and the combination of these procedures, comparing the results with a flatfoot scenario and a triple arthrodesis case.

Methods: Simulations were performed using a finite element model, reconstructed from CT-images of a healthy patient. A 10-mm OMC was simulated. The talonavicular joint was simulated replacing the joint cartilage by cortical bone. The model includes the geometry of all the foot bones, the plantar fascia, cartilages, plantar ligaments, Posterior tibialis tendon, Peroneus tendons, and Achilles tendon, respecting their anatomical distribution and biomechanical properties (Figure 1-A). The simulations were carried out simulating the mid-stance gait phase [4]. The flatfoot scenario was simulated reducing the traction force in the Tibialis Posterior tendon and weakening both the spring ligament and plantar fascia. The simulations were evaluated comparing the stress maximum values of each simulation with the bone stress generated in a healthy foot and measuring both the Internal Moreau-Costa-Bertani and forefoot abduction angles.

Results: Result shows that the combination of talonavicular arthrodesis with OMC, reduces the forefoot stress in about 38% versus triple arthrodesis results (Figure 1-B). Additionally, structural correction achieved was very close to which was obtained with the triple arthrodesis simulation (Table 1).

Conclusion: The combination of OMC with talonavicular arthrodesis could be consider as an alternative to triple arthrodesis. This combination generates significant stress reduction in foot forefoot, which means less risk to develop a long-term toes pain. Additionally, this alternative is considerably less restrictive than triple arthrodesis.

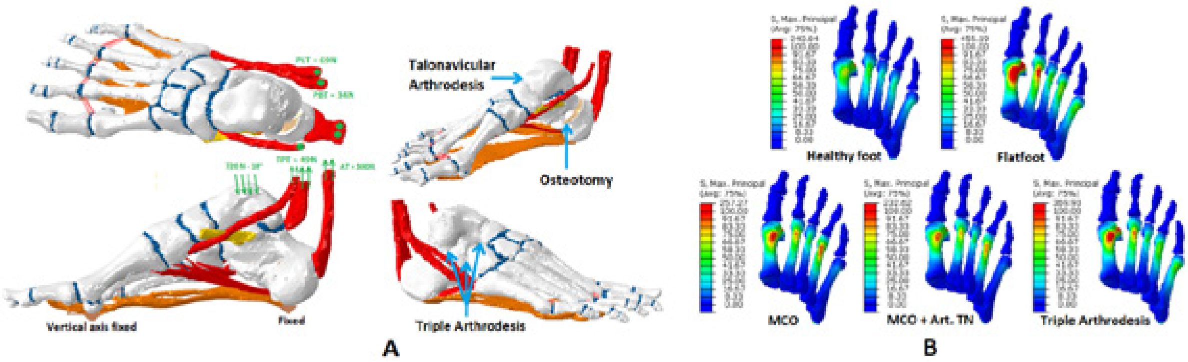

Figure 1. A.: Finite element model used in this study. The figure shows the basic model and the loading conditions used, and how arthrodesis and medializing calcaneal osteotomy were simulated. **B.:** Results of the biomechanical stress obtained in the forefoot bones.

	Healthy	Flatfoot	MCO	MCO + Art. TN	Triple Arthrodesis
IMCB Angle	115	120	117	116	115
Forefoot Abduction Angle	16	24	17	14	15

Table 1. Results of the Structural correction obtained. Both the Internal Moreau-Costa-Bertani (IMCB) and the forefoot abduction angles were measured, for all the simulated cases. All values were measured in degrees.

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Soft soled footwear has limited impact on toddler gait

Introduction

The development of walking in young toddlers is an important motor milestone. Walking patterns can widely differ amongst toddlers, and are characterised by unique biomechanical strategies. This makes comparisons between newly walking toddler's and older children's walking difficult. Little is currently understood regarding the effects of footwear on the gait in newly walking toddlers. Therefore, this research aimed to assess whether spatiotemporal parameters of gait, and in-shoe foot and lower limb kinematics, differ when walking barefoot and in soft soled footwear, in newly walking toddlers.

Methodology

A quasi-experimental pre-post study design was used to assess spatiotemporal parameters of gait, and in-shoe foot and lower limb kinematics. The GAITRite system collected spatial and temporal data. The Vicon camera system collected kinematic data. The testing conditions included barefoot and footwear. Footwear tested was a commercially available generic soft soled shoe with a Velcro fixture, structured soft leather upper and flexible heel counter. Data was extracted directly from the GAITRite system and analysed. Kinetic data was cleaned and imported to OpenSim for analysis. Differences between barefoot and footwear conditions were analysed with linear regression analysis clustered by individual participant, therefore no height normalisation was used to account for any variations in leg length or height. Robust estimates were used to account for the within-subject nature of the data. The mean difference, 95% confidence intervals, p value and effect size were used to understand any differences between walking barefoot and walking in footwear.

Results

There were 14 toddlers (mean(SD) age = 13.3(2.7) months) underwent testing, and kinematic data collected from 13 of the 14 toddlers. Walking in footwear did not change spatial or temporal data, however there were small but significant decreases in hip adduction/abduction range of motion (mean difference (MD)=1.79°, 95% CI=-3.51 to -0.07, p=0.04), knee flexion (MD=-7.63°, 95% CI=2.70 to 12.55, p=0.01), and knee flexion/extension range of movement (MD=6.25°, 95% CI=-10.49 to -2.01, p=0.01), and an increase in subtalar joint eversion (MD=2.85°, 95% CI=5.29 to -0.41, p=0.03) . Effect sizes were small for hip and ankle range, peak knee extension, and subtalar joint ranges (d<0.49), medium for knee flexion/extension range (d=0.75) and large for peak knee flexion (d=0.87).

Conclusions

The magnitude of kinematic changes with soft-soled footwear were small thus the clinical importance of these findings is uncertain. Future longitudinal studies are needed to develop recommendations regarding footwear for newly walking toddlers.

State of the art in footwear biomechanics in diabetic foot disease

Dr. Sicco A. Bus

Foot disease is a major problem in people with diabetes mellitus. Every 30 seconds someone in the world loses a leg because of diabetes. A foot ulcer precedes most amputations. Increased mechanical pressure on the foot during ambulation is an important risk factors for foot ulceration. Therefore, reduction of these pressures is important both in the prevention and treatment of these chronic wounds. For ulcer prevention, custom-made footwear is commonly prescribed to people with diabetes, in particular to those that have healed from a plantar foot ulcer and have foot deformity that limits the use of standard footwear. Custom-made footwear aims to redistribute pressures on the foot and reduced pressure at locations that are a high risk for ulceration (pressure points). International guidelines from the IWGDF report on the importance of custom-made footwear and insoles to prevent recurrence of plantar foot ulcers in patients in remission. Innovations in footwear technology include the use of plantar pressure measurements to guide design and modifications to the footwear that optimize the pressure relieving properties of the shoe. The efficacy of this approach has been tested in several trials. These trials show that barefoot or in-shoe plantar pressure measurements can improve the footwear of high-risk patients with diabetes, and can lead to better clinical outcomes in prevention. Further innovations include the development of scientific-based protocols to help in clinical decision-making for the right type of footwear and for the design of custom-made footwear for different levels of foot complications. Other innovations include the testing and comparison of scientific-based pressure-based footwear design on plantar pressure relief, of which the results can help in moving towards designing the most optimal shoe for diabetic foot prevention. Other innovations will also be presented during this lecture

Strategic implications of the development of cone beam WBCT

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Weight Bearing CT is now quickly becoming the new norm for foot and ankle and soon lower limb MSK research. More widely, Cone Beam CT is becoming the new norm in lower and upper limb imaging.
Being currently at a technological cross-roads where Artificial Intelligence is meeting with 3D imaging, the whole scientific, industrial and financial community gravitating around these technologies is facing an unprecedented challenge and must come together to streamline the production of 3D models of the foot and ankle, to provide intelligent, data based analysis. This will help providing improved diagnostic, prognostic and therapeutic solutions.
We will discuss how this transformation is coming about and how we, as clinicians and engineers can act to ensure that it coincides with the best interests of patients.

Subject-specific geometric definition and validation of a novel kinematic model of human hind+midfoot

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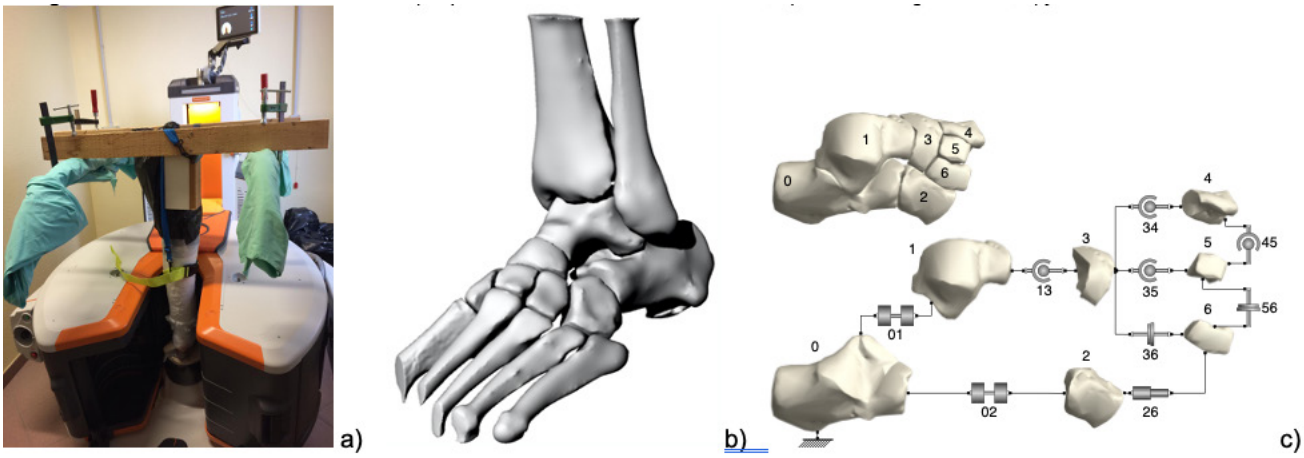
Emergent medical imaging techniques are very promising in orthopaedics, both for diagnosis and for developing new treatment strategies. In particular, Cone-Beam CT (CBCT) allows fast and detailed scans also in weight-bearing conditions (Figure 1a). This opens the way to accurate personalized models of patients' joints under realistic loading conditions, also for complex structures like the ankle and foot (Figure 1b).

Multi-segment models of the kinematics of the human foot generally propose its segmentation into a limited number of bony segments [1] and only a few models include kinematic constraints. A new analytical model for the relative motions of hind+midfoot bones has been developed [2], including a representation of all single bones and corresponding joints (Figure 1c). This model is purely kinematical and regards this foot bone complex as a system of rigid bodies with perfect mutual constraints. The kinematic chain consists of seven bones and nine relevant joints: four ball-and-sockets, two plane-on-planes, one cylindrical joint, and two hinges.

A relevant experimental procedure was devised to configure and validate the model on a subject-specific approach. A lower limb specimen from the hip to the foot was used. The whole leg was casted except the ankle and foot, to avoid any motion at the knee. A wooden structure was fixed with clamps at the CBCT structure (Figure 1a) to keep the leg vertical. Different wedges were used to impose 5 dorsi/plantarflexions, each with 3 ev/inversion positions, for a total of 15 different configurations for the ankle. Two different loading conditions were considered for these configurations: no loads and 350N applied along the long axis of the leg, i.e. vertical, to represent patient weight. Two additional loading conditions were taken at the neutral ankle position: an internal and external torsion about the vertical axis, and an external torsion about the long axis of the foot. These overall 33 foot-and-ankle configurations were scanned by CBCT and were then segmented using a proprietary semi-automatic procedure. This series of bone configurations was used to obtain the model parameters for the bones and the joints, and to validate the model itself.

The entire experimental procedure for these measurements runs smoothly, supporting further similar specimen specific analyses. The resulting configuration of the kinematic model was found practicable and anatomically consistent, with the comparison between model predictions and observed motion concurring well. Inclusion of forefoot bones and ligaments is under development.

Figure 1. Model definition and validation: a) experimental measurements in CBCT; b) results of segmentation; c) joint model definition.



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Subject-Specific Prediction of Soft Tissue Structures In The Ankle Joint

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Introduction

For a full understanding of the function of the ankle joint, simultaneous analysis of three-dimensional (3D) bony and soft-tissue structures is essential. 3D musculoskeletal models have become pivotal in orthopedic treatment planning as well as orthopedic and biomechanical research. Knowledge of the anatomical-geometrical manipulation of bone and neighboring soft tissue structures is essential for safe computed preoperative planning, during navigated and robotic-assisted surgical applications, and for the correct interpretation of postoperative outcomes. Because manual segmentation of these models is time-consuming and subject to manual errors, (semi-) automatic methods (1) could improve the accuracy and enlarge the sample size of subject-specific 'in silico' biomechanical experiments.

Methods

Originating from a previously 'in-house' generated lower limb skeletal model (N=600) and 10 manual tibiotalar cartilage and ankle ligament MRi segmentations, a subject-specific cartilage and ligamentous prediction algorithm was described using statistical shape modelling and geometric morphometrics (Figure 1). For cartilage, a population-averaged point-specific cartilage thickness map was calculated. Cartilage was modelled by extruding the subchondral bone by the point-specific thickness. Ligaments were wrapped around bony contours based on iterative shortest path calculation. Relevant ligaments that were included consisted out of the AITFL, PITFL, ATFL, PTFL, CFL, Tibiocalcaneal fascicle of the superior deltoid ligament (TCL), Posterior Tibiotalar fascicle of the superior deltoid ligament (PTTL),Deep Deltoid Ligament (DDL), Cervical Ligament (CL), and interosseous talocalcaneal ligament (IOTCL).

Experiments and Results

Accuracy of ligament topography and cartilage thickness prediction was quantified using leave-one-out experiments and described as Mean Distance Error (MDE) and Root-Mean-Square Error (RMSE). Furthermore, we compared our population-averaged ankle cartilage model to a constant thickness ankle cartilage model, commonly used in biomechanical studies (2). MDE of ligament and cartilage prediction was 0,391 and 0,243 mm,respectively (Table 1). As opposed to the subject-specific cartilage thickness, the average error of a constant thickness cartilage was 0,574 mm (Table 2).

Discussion

Parallel to the technological advances in computer-aided orthopedic surgery, musculoskeletal modeling has evolved greatly and appears to be close on the verge of integrating biomechanical simulations of soft tissue structures with intra-operative image guidance on bony anatomy. Such near future improvements require general data that can bridge the gap between the two technological modalities.

We have shown that our novel prediction methodology was able to predict the cartilage and main ankle ligaments with submillimeter accuracy. The proposed method has a high potential for generating large (virtual) sample sizes in biomechanical research, as well as opens the door for technological advances in orthopaedic surgery.

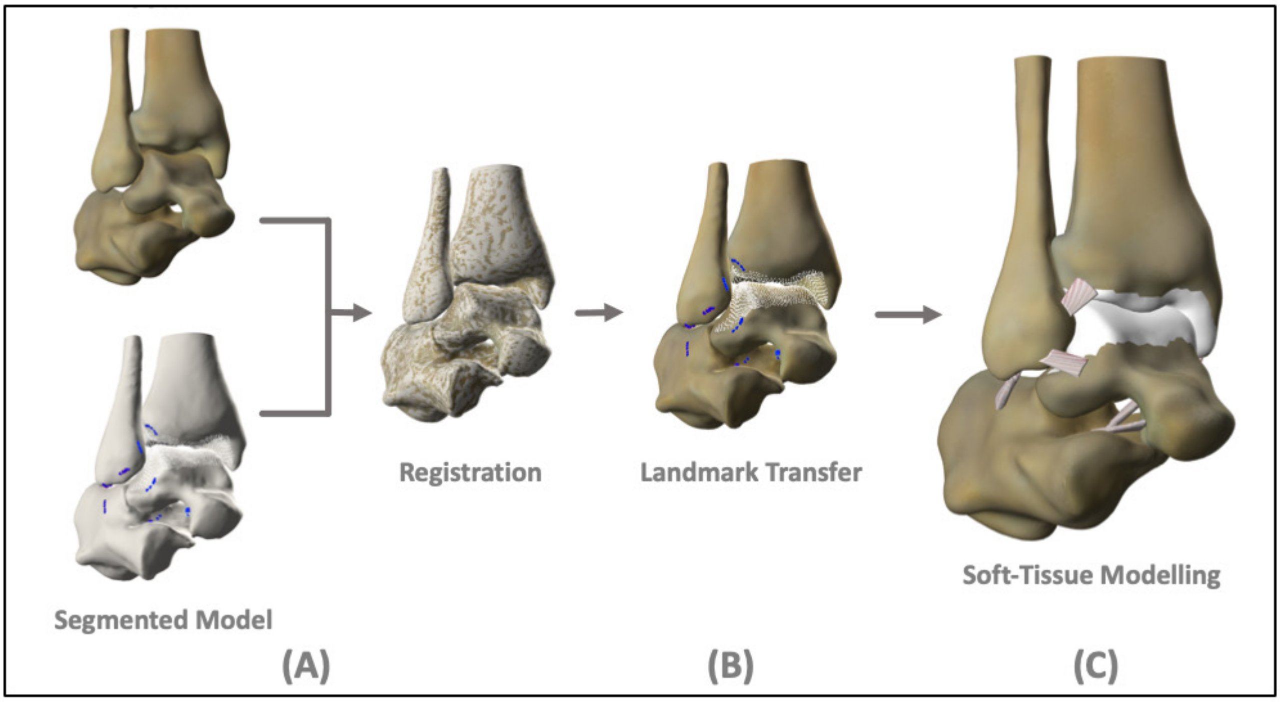
Table 1. *Ligament Validation.* MDE and RMSE of segmented versus each predicted ligaments are reported, as well as mean MDE and RMSE.

	AITFL	PITFL	ATFL	PTFL	CFL	PTTL	TCL	DDL	CL	ITCL	MEAN
MDE (mm)	0,354	0,063 063	0,433	0,164	0,544	0,623	0,771	0,175	0,725	1,575	0,391
RMSE (mm)	0,535	0,233	0,582	0,329	0,688	0,789	0,996	0,541	0,919	1,697	0,636

Table 2. ***Cartilage validation.*** For Talus and Tibia, MDE and RMSE are calculated and compared.

	Talus		Tibia	
	Point-Specific Thickness	**Constant Thickness**	**Point-Specific Thickness**	**Constant Thickness**
MDE (mm)	0,249	0,555	0,237	0,593
RMSE (mm)	0,319	0,703	0,313	0,755

Figure 1. ***Flowchart of the ligament and cartilage prediction algorithm****. (A) Firstly, the segmented ankle bones (bottom, grey) with corresponding ligament origin/insertion vertices (bottom, blue) and cartilage vertices (bottom, white) are fitted to the SSM (top, brown). (B) In doing so, the landmarks are accurately projected onto the SSM. (C) From the projected landmarks, the ligaments and cartilage are modelled on the SSM. This combined bony and soft-tissue ankle model will be used to predict cartilage and ligaments onto newly segmented bony models.*



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Subtalar Joint dependent Muscle Function of the M. Tibialis Anterior

Introduction

Remarkable inter-individual variation in subtalar joint orientation has been reported excessively (Isman, Inman, & Poor, 1969; Lewis et al., 2009; Lundberg & Svensson, 1993; Manter, 1941; Reule, Alt, Lohrer, & Hochwald, 2011). Mechanical consequences, although often discussed, have been rarely investigated. Klein et al. mentioned for the m. tibialis anterior that "Shortening [...] induced only a small inversion, and even in some specimens [...] an eversion moment arm". Consequently, we hypothesized, that m. tibialis anterior changes its joint function with respect to individual subtalar joint axis orientation.

Methods

Subtalar joint orientation was estimated in 16 healthy joints (8 m/8w) using an inertial measurement unit (IMU) based system developed and validated in Schlechtweg, Hauser, & Alt (2019). The system uses a kinematic constraints model mentioned by Seel & Schauer (2012) to infer the joint axis between two segments. One IMU was placed on the tibia edge in random orientation. The second IMU was rigidly connected to a flat plate, orientated such that the sensor's *z,y-Plane* was parallel to a thin line on the plate and the *x,y-Plane* was parallel to the ground. This plate was fixed plantar on the foot such that the thin line was parallel to the midline of the foot in the definition of Manter (1941) and Hochwald (2007). M. tibialis anterior was stimulated electrically using Compex SA Sport stimulator. The electrodes were trimmed to minimize the risk of co-contraction. Following a ramp test to fit the optimal stimulation parameters for a maximum motion, three external muscle contractions were induced with 30 sec. delay. Resulting motion was recorded for analysis.

Results

Seven subjects showed a supination and dorsiflexion and 9 subjects a pure dorsiflexion. Descriptive subtalar joint orientations are shown in Table 1. The orientations grouped by annotated motions are shown in Figure 1.

Discussion

Based on the data, the hypothesis, that the motion induced by the m. tibialis anterior is related to the individual subtalar joint orientation, was verified. The motion was discriminated by the orientation almost perfectly. However, one outlier was observed in the supination group and an expected pronation at higher deviation angles did not appear. Results indicate, that there is a muscle function dependency from subtalar joint orientation. This might play an important role, especially in the development of chronic overuse injuries.

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Tables and Figures

	Deviation	Inclination
Mean	5.17	47.06
SD	4.13	6.11

Table 1: Descriptive Statistics

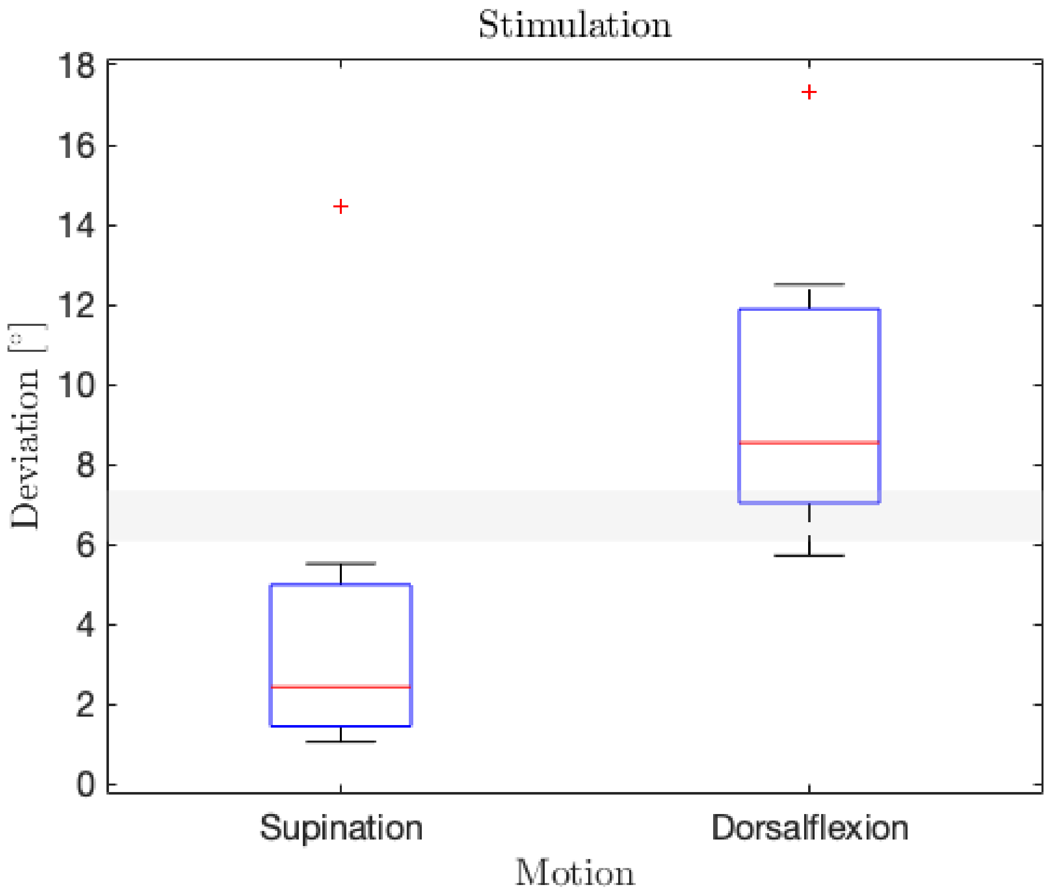

Figure 1: Observed motion in the foot with corresponding deviation angle. Red line represents the median; red star indicates an outlier. Grey area indicates the 95% confidence interval between the two motions based on the deviation angle. Motions were discriminated almost perfectly by the subtalar joint orientation

The Collapsing Foot: Challenges in Diagnosis & Treatment & The Role of the Weight-Bearing CT

Cesar de Cesar Netto

University of Iowa, Iowa City-IA

In this lecture we are going to talk about the evolution in the diagnosis, radiographic assessment and treatment of the collapsing foot and why terms such as posterior tibial tendon dysfunction and adult acquired flatfoot deformity are not enough to describe this complex three-dimensional derangement of the foot and ankle. We will discuss preoperative, intraoperative and postoperative radiographic assessment of deformity correction, and the multiple measurements reported in the literature, as well as how the advent of weightbearing CT has changed the understanding, the staging and the treatment algorithm for the collapse of this biomechanical and anatomical masterpiece that we know as foot.

The comparison of foot clearance in infant gait in novice to experienced walkers using statistical parametric mapping

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Introduction: The ability to clear the foot during swing has been proposed as a key requirement for the development of independent walking [1]. Foot clearance in infants differs to that in adults and therefore the discrete data (e.g. local minimum and maximum of trajectories) used to quantify it may not be appropriate. As part of a wider longitudinal study we compared the clearance of the foot during swing between novice and experienced infants using statistical parametric mapping (SPM).

Methods: Fifteen infants from a wider study participated in two test sessions. Firstly, within 3 weeks of taking five independent steps (age 411±73 days) then again (average 81±28 days later) when they could walk in a confident stable manner (age 490±84 days). Retro-reflective markers (20x6.5 mm) were used to define the feet, lower limbs and pelvis. Infants walked in a child-friendly laboratory while kinematic data were collected (Qualisys, Sweden; 100 Hz). Vertical foot (1st and 5th metatarsal heads and heel) marker trajectories were tracked and trajectories during swing were exported from Visual 3D (C-Motion, USA). Five to ten swing phases were averaged for each infant for each session. Trajectories were compared for novice versus experienced walkers utilising paired sample SPM1D t-tests in Python [2].

Results: SPM of the three foot marker trajectories identified significant differences. The 5th metatarsal head of the left foot mid- and terminal-swing recorded significantly higher foot clearance in the novice walkers (Figure 1). A phase of terminal-swing also recorded significantly higher foot clearance in novice walkers for the left heel (Figure 2).

Discussion: From previous literature, we anticipated the novice walkers to be less capable to clear their feet above the floor, however their foot clearance values were higher than the experienced walkers for some trajectories. This is consistent with other literature comparing first steps to more experienced walkers [3]. In mid-swing we can propose this is to reduce the risk of trips due to ineffective ground clearance. In terminal swing these higher heel foot clearance values reflect a midfoot contact with the floor, as opposed to a contact with the heel. From our SPM analysis, we offer a more detailed comparison of infant gait characteristic than would have been identified with discrete values.

Relevance: Novice and experienced independent walkers can be separated by their foot trajectory if the entire swing phase is considered.

References: 1 Hallemans 2005 *Thesis* **2** Pataky 2016 *spm1d package (Version 0.4.3)* **3** Dominici et al 2007 *J Neurophysiol 97(4):2790-801*

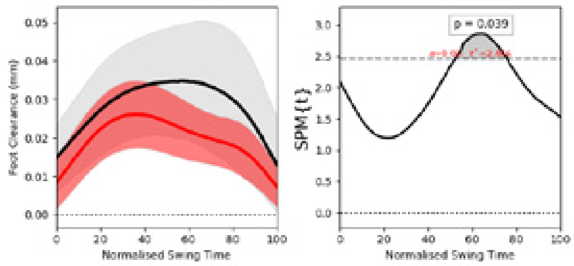

Figure 1 L- mean foot clearance for left 5th metatarsal vertical trajectory for novice (black) and experienced (red) walkers. R- the paired samples t-test statistic SPM {t}. The critical threshold of 2.464 (dashed line) was exceeded between time 52-75% of swing with a supra-threshold cluster probability value of p = 0.039 indicating a significantly higher foot clearance in the novice walkers.

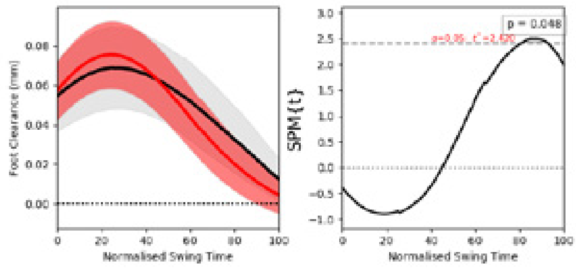

Figure 2 L- mean foot clearance for left heel vertical trajectory for novice (black) and experienced (red) walkers. R- the paired samples t-test statistic SPM {t}. The critical threshold of 2.420 (dashed line) was exceeded between time 81-92% of swing with a supra-threshold cluster probability value of p = 0.048 indicating a significantly higher foot clearance in the novice walkers.

The continued search for Achilles tendinopathy pain mechanisms and role of weight-bearing CT

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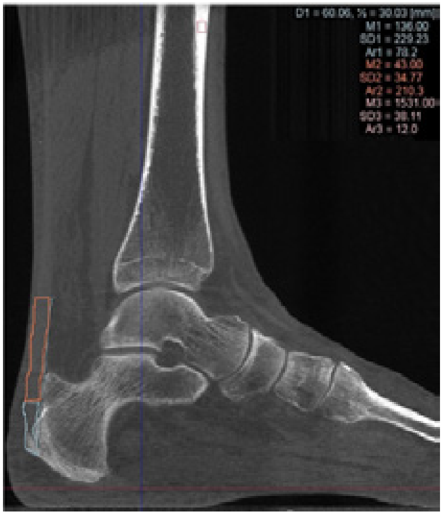
Background: Achilles tendinopathy is a common cause of pain, yet the mechanisms behind pain remain elusive[1]. The load on the Achilles tendon is consistently indicated as a primary means of developing and aggravating Achilles tendinopathy symptoms [2]. The bone formation is one potential marker of load on the Achilles tendon where evidence from prehistoric human data[3] and an animal model[4] suggests that the development of osteophytes within tendon is a normal response to cumulative mechanical loading with aging and activity. In addition to age and activity, BMI and foot posture are also commonly recognized risk factors for Achilles tendinopathy and could also exacerbate loading within the tendon[2]. Weight-bearing CT (WBCT) provides a unique opportunity to objectively quantify signs of tendon load (e.g. bone formation within the tendon) and foot posture.

Objectives: The first objective of this study was to examine the reliability of WBCT measures to quantify 1) bone formation within the Achilles tendon, and 2) foot posture. The second objective was to examine the association between the severity of bone formation within the tendon with known risk factors, including age, BMI and foot posture, in patients with Achilles tendinopathy pain and age-, gender-matched controls.

Methods: 6 patients with Achilles tendinopathy (Mean(SD), Age=60.8(11.2) years, BMI=34.7(7.3) kg/m^2, 83% female) and 6 controls (Age=59.1(10.7) years, BMI=33(7.0) kg/m^2, 83% female) had WBCT as part of routine care. Demographics were collected from a retrospective chart review. All WBCT measures were completed using CurveBeam CubeVue software by two independent raters. Foot posture was quantified using the foot ankle offset (FAO) measure with the TALAS tool within CubeVue. Severity of bone formation within the tendon was quantified by the peak Hounsfield Unit (HU) for the Achilles tendon insertion (0 to 2cm from distal insertion, blue outline in figure) and midportion (2 to 6 cm, orange outline in figure) identified in the sagittal plane after scrolling through medial to lateral cuts. Cortical bone of the tibia or metatarsals were used as a patient-specific reference for max HU. Severity of bone formation in the tendon was also quantified by volume of the bone within the tendon measured in the transverse view for the entire length of each osteophyte identified in the sagittal plane view.



Results: Preliminary results support high inter-rater reliability of WBCT measures (FAO, ICC= 0.97). Preliminary results also support the validity of utilizing HU to quantify severity of bone formation within the tendon with significantly higher mean and intratendinous variation in HU in patients with AT (mean=127(76.4), variation=252.9(104.4)) compared to controls (mean=-10.7(45.9), p=0.003; variation=114(55.5), p=0.017). There was a moderate positive correlation between older age and higher HU (Spearman's rho= 0.396) among patients and controls.

Discussion: Future research is needed to examine how these markers of tendon load and foot posture change with conservative and surgical treatment.

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The diabetic foot prevention: how model-based assessment of plantar tissues internal stresses can inform clinical practice

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Introduction

Chronic diabetes complications represent the most relevant problem in terms of clinical management and healthcare system costs linked to diabetes [1]. Ten years after disease onset, between 20 and 50% type-2 diabetic patients develop diabetic peripheral neuropathy (DPN), which is a major risk factor for diabetic foot problems. Recently physical therapy protocols aiming to strengthen the intrinsic and extrinsic foot muscles showed to improve lower extremity function in DPN subjects [2]. The aim of this study was to determine the relationship between intrinsic foot muscle forces and foot internal stresses and strain through musculoskeletal modelling.

Methods

Ten subjects were analyzed (Table 1). A stereophotogrammetric system (BTS) synchronized with 2 pressure plates (Imagortesi), 2 force plates (Bertec), and a 16 channels surface electromyographic system (BTS) were used for gait analysis, adopting a 3D multi-segment foot markerset with a full body one for kinematics [3]. In term of musculoskeletal modelling, two 6DOF foot models were generated: one with (Inner) and one without (No Inner) intrinsic foot muscles [4]. Two FEMs, one for the controls and one for the DPN subjects, were defined with respectively a healthy and a diabetic foot geometry (from MRI) [5]. Subject-specific kinematics, muscle forces and ground reaction forces were applied as boundary conditions. Four phases of the gait cycle were simulated and simulated plantar pressures were validated against the experimental ones [5]. Kruskal-Wallis test ($p<0.05$) was used to compare the results between the two cohorts of subjects and between the two approaches. RMSD was calculated between measured and simulated plantar pressures.

	Age (mean ± SD) [years]	BMI (mean ± SD) [kg/m^2]
5 Healthy Subjects (HS)	44.20±16.66	21.53±1.13
5 DPN	58.40±7.76	25.93±2.67

Table 1: Healthy Subjects and Diabetic Neuropathic Subjects data

Results

DPN displayed significantly higher internal stresses at soft tissues (Fig.1 Top) associated with higher intrinsic muscles forces (Fig.1 Bottom) than the HS. In term of validation results, the maximum RMSD, between experimental and simulated plantar pressure, was registered at the hindfoot, and the Inner model showed the best performance. The latter showed lower Von Mises stresses at initial contact and loading response while higher stresses at midstance and push-off phases.

Discussion

The intrinsic muscles played an important role in distributing the internal stresses at the plantar aspect of the foot. The interdependency of muscle force and tissue response justifies a concurrent multiscale-modeling approach. Moreover, the subject-specific foot morphology and biomechanics should be accounted for achieving optimal offloading, or planning intervention aiming at restoring foot muscle function in DPN.

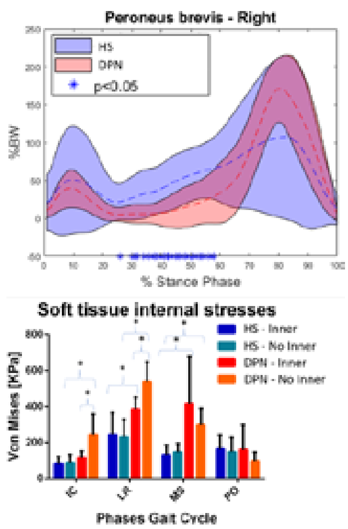

Figure 1: Top: Peroneus brevis force (mean± SD)
Bottom: Soft tissue internal stresses

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The effect of a split outsole on intrinsic foot kinematics and lower leg muscle activities during normal walking

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Split sole shoes have a special outsole that is not connected at the mid-foot region, allowing higher foot flexibility (Figure 1). Improved flexibility may improve performance in physical activities, as well as decrease the risk of injuries, by allowing the lower extremity joint to move through a full range of motion [1, 2]. The purpose of this study is to examine the biomechanical effects of the split sole design on a normal gait through kinematic analysis and electromyography (EMG).

Fifteen subjects (15 females, 21.7 ± 0.8 years) were recruited. Subjects were required to walk in split sole shoes and the control shoes with a single rigid outsole. Kistler force plates and a motion capture system were used to record the walking trials. The AgCl electrodes for measuring EMG was patched on the five lower limb muscles: tibialis anterior, peroneus longus, gastrocnemius, rectus femoris, and biceps femoris. T-test was used between two sole types with the significance level 0.05 for the kinematic data and EMG.

Knee flexion angle was found to be significantly higher during the mid-swing phase when subjects walked in split sole shoes. Ankle plantar flexion angle was significantly lower during the terminal stance to initial swing phase in split sole shoes (Table 1). In the EMG results, the control shoes activity was higher significantly than the split sole activity in the transition period of the tibialis anterior from the stance phase to swing phase. The split sole activity was higher significantly than the control shoes in the mid-stance of the peroneus longus, the transition period of the rectus femoris, and the mid-stance and initial swing of the biceps femoris.

Flexion at the knee and ankle during the swing phase can potentially be used to allow a reduction in compensatory mechanisms by easing swing foot ground clearance [3]. Tibialis anterior is involved in the foot dorsiflexion and the inversion. The abnormal inversion strains the foot ankle, so the risk of injury increases. By securing flexibility of the feet, the tibialis anterior activity for foot inversion decreases and the injury risk declines in the split sole shoes. The peroneus longus maintains the foot transverse arch during the gait, and the rectus femoris and the biceps femoris limit the abnormal rotation of hip and knee.

Figure 1. (A) Control shoes with a single rigid outsole, (B) Split outsole shoes

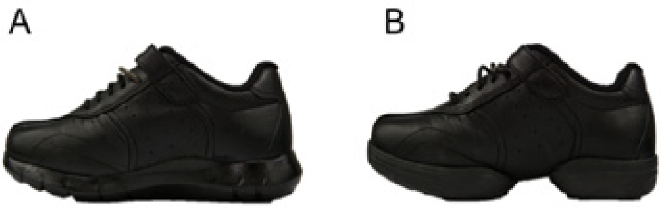

Table 1. Average flexion angles for gait cycle interval

	(%)	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100
KNEE	SSS	7.26±3.63	14.89±3.38	11.81±2.84	8.10±0.00	8.35±2.82	19.53±3.73	48.87±5.09	65.98±4.26	48.05±5.71	13.68±4.44
	Control	7.59±5.07	15.28±6.43	12.03±5.20	8.08±2.85	8.35±2.99	19.70±5.10	48.87±6.00	64.66±4.20	46.26±6.30	12.63±6.79
ANK	SSS	-2.24±2.89	-1.89±1.82	4.02±1.74	9.02±0.00	14.14±1.71	10.45±3.89	-10.74±5.09	-6.26±4.02	2.08±2.77	2.06±2.68
	Control	-2.72±2.46	-1.90±2.10	3.52±2.05	8.19±2.02	13.27±2.09	8.23±3.76	-13.10±4.90	-6.69±3.19	1.23±2.53	1.67±2.79

Values are the mean ± SD (°). Gray box shows P<=0.05. SSS=Split Sole Shoes

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The Effect of Attending Physical Rehabilitation After the First Acute Lateral Ankle Sprain on Landing Forces in Patients with Chronic Ankle Instability

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Introduction: Altered biomechanics are commonly identified among individuals with chronic ankle instability (CAI) [1,2]. Emerging evidence suggests individuals with CAI who sought medical attention after an initial ankle sprain reported fewer subjective symptoms and demonstrated better static balance [3]. However, it is unknown if receiving supervised physical rehabilitation has a similar effect on other important outcomes, such as the ground reaction force (GRF) exhibited following a jump landing. Therefore, the purpose of this study was to compare landing GRF between participants with CAI who did or did not self-report attending supervised physical rehabilitation following a previous lateral ankle sprain. **Methods:** Nine individuals with CAI who reported completing supervised ankle rehabilitation following their initial acute ankle sprain (age: 22.7±4.1 years; height: 168.0±9.2 cm; mass: 74.2±11.4 kg) were compared to 13 individuals with CAI who reported never completing supervised ankle rehabilitation (age: 23.9±4.1 years; height: 168.5±9.8 cm; mass: 68.5±14.5 kg) in this case-control study. All participants completed a jump-landing task requiring them to jump from two feet, touch a marker set to 50% of their maximal vertical jump height, land on a single-limb, and maintain balance for three seconds. Kinetic data were collected at 1000 Hz using a Bertec force plate embedded in the laboratory floor and filtered with a low-pass forth-order Butterworth Filter at a frequency of 12 Hz. The variables extracted from the force plate included peak vertical GRF (vGRF), time to peak vGRF, and the vGRF slope. Three trials were collected per participant and averaged for statistical analysis. Separate independent *t*-tests with corresponding effect sizes (d) were used to compare each variable between groups. **Results:** Participants who reported participating in supervised rehabilitation after a previous ankle sprain had a lower peak vGRF (p=0.017, d=0.95) (Table 1). No significant differences were identified between groups for time to peak vGRF (p=0.868, d=0.07) or the slope of the vGRF (p=0.079, d=0.77). **Discussion:** These findings indicate that amongst individuals with CAI, not attending supervised rehabilitation may contribute to deleterious force absorption strategies during tasks such as jump landing as indicated by greater peak vGRF. Therefore, clinicians should continue to advocate for patients recovering from an acute ankle sprain to seek physical rehabilitation to address impairments which may alter biomechanics after injury. **Relevance**: Supervised rehabilitation may positively alter loading patterns after ankle sprain injuries which may have long term benefits for mitigating subseqeunt injury risk and promoting joint health.

Table 1. Group means ± standard deviations for all primary outcome measures.

	Supervised Rehabilitation (n = 9)	No Previous Rehabilitation (n = 13)	p-value
Peak vGRF (%BW)	248.36 ± 22.27	315.53 ± 85.43	0.017
vGRF slope (%BW/ms)	3.02 ± 0.50	3.66 ± 0.94	0.079
Time to Peak vGRF (ms)	99.67 ± 11.53	100.33 ± 7.05	0.868

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The effect of footwear on arch-ligament dynamics: a pilot study

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Introduction

Numerous studies have quantified differences in mechanics across barefoot, minimal and cushioned shoes [1]. It remains unclear how shoes affect the mechanics of the medial longitudinal arch. It has been suggested that barefoot running promotes arch deformation and recoil, enhancing the foot's ability to manage energy through excursion of arch ligaments [2]. In this pilot, we examined how shoes affect arch function using a rare dataset of foot bone motion captured with dynamic x-ray. We hypothesized that arch range of motion (ROM) would be greatest during barefoot and least with a cushioned shoe. Further, we investigated how changes to arch dynamics altered elongation of the arch ligaments.

Methods

One subject (male, 51Y) with beads implanted in his foot bones performed multiple running trials in cushioned shoes (New Balance 940V2), minimal shoes (Xero Prio) and barefoot. CT scans of the subject's foot yielded 3D models of the foot bones. The subject was instructed to run with a rear-foot strike at a self-selected speed while biplanar videoradiography tracked the 3D position of the beads and corresponding bones. Motion of the first metatarsal relative to the calcaneus quantified three-dimensional arch motion. The long plantar ligament (LPL), short plantar ligament (SPL), and calcaneonavicular ligament (CNL) were modelled as the shortest path from origin to insertion under the constraint that bone surfaces were not penetrated.

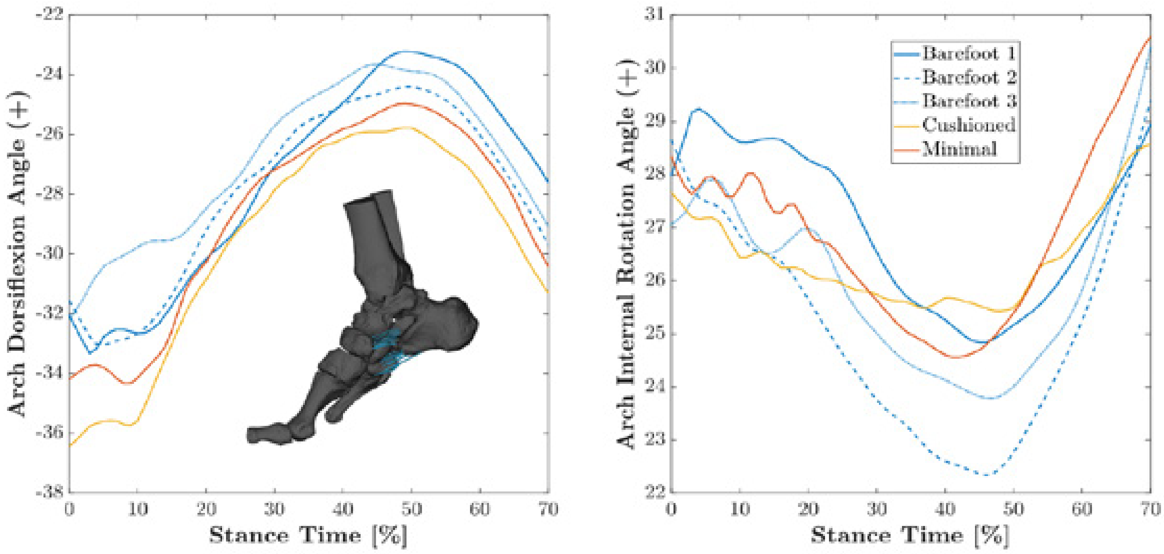
Results

Shod trials consistently presented with higher arch dorsiflexion at contact (35.3° shod versus 31.9° for barefoot). All ligaments in shod trials were initially less strained relative to barefoot. The arch experienced a 26.4% (2.1°) increase in dorsiflexion range of motion and the CNL displayed a 23.8% (0.14mm) increase in elongation when shod. Arch internal-external ROM was reduced in the shod case however, dropping by an average of 66.1% (4.2°), which likely reduced elongation of the LPL and SPL by 11.5% (1.7mm) and 16.2% (1.9mm) respectively.

Discussion & Conclusion

While it is difficult to generalize our findings, we found that both minimal and cushioned shoes raised the arch compared to barefoot. Shoes increased sagittal arch motion and restricted transverse plane motion, which altered the arch ligaments' elongation. The CNL's greater ROM may be due to its alignment with the longitudinal arch, while LPL and SPL ligaments are more sensitive to internal rotation. Interestingly, shoes altered arch and ligament dynamics relative to barefoot regardless of type. It remains unknown whether similar behavior would be observed with a forefoot strike gait.

Figure 1: Visualization of arch dorsiflexion with ligament model (left) and internal/external rotation (right).



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The effect of heel height on initial contact in children

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Introduction

Heeled shoes are a popular footwear design and whilst emphasised in women's footwear, they are present in men's and children's shoes too. The research base focuses on women's footwear and heeled shoes force the ankle joint into plantarflexion altering how the foot interacts with the ground. Though heel-height is lower on children's shoes, there is little understanding of how heel-height impacts joint kinematics. From previous literature (Ebbeling et al., 1994; Snow et al., 1994), we assume that compensations at the ankle or knee mitigate the closed chain effect of heeled shoes proximally. The purpose of this study is to investigate the effect of heel-height on initial contact in children by comparing three heel-heights to one another and barefoot walking.

Methods

Eleven healthy children (5 males) aged 7-11 years were assessed while walking barefoot (BF), in an on- market product (SH1), on-market product +5mm heel-height (SH2) and +10mm heel-height (SH3) (Table 1). Heel elevation was altered by attaching/inserting an EVA wedge (Figure 1). Kinematic data was collected using 11 Qualisys ProReflex cameras at 100 Hz. 26 5mm markers defined the right limb and four tracking markers on the left foot were used for event detection. A static standing trial and a virtual foot model were used to define 0° at the ankle. Gait events were defined using foot velocity (O'Connor *et al.*, 2007).

	Boys	Girls
SH1	35mm	15mm
SH2	40mm	20mm
SH3	45mm	25mm

Table 1. Shoe heel-heights for boys and girls

Figure 1. Example of the location of the shoe modification for boys (left) and girls (right)

Results

Raising heel-height increases peak ankle dorsiflexion at initial contact across all conditions (Table 2.). The largest dorsiflexion angle is observed in the highest heel (SH3). This angle is significantly different from that observed barefoot in boys (P=<0.05) but not girls (P=>0.05). An increase of 17% and 34% is observed between SH1 and SH3 for boys and girls respectively (P=>0.05).

Table 2. Percentage difference in peak ankle dorsiflexion angle at initial contact compared with barefoot walking.

	SH1	SH2	SH3
Boys	27%	34%	44%
Girls	17%	34%	51%

Conclusion

Increasing heel-height systematically alters ankle dorsiflexion angle at initial contact. Footwear manufacturers should be aware of the association between their design decisions and these effects to ensure that it is appropriate for the target market and the activities they participate in.

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The effect of induced joint restriction on plantar pressure distribution

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Introduction: Research shows that diabetic peripheral neuropathy is related to altered joint kinematics during gait [1,2,3]. However, it is still unclear whether joint movement directly influences plantar pressure distribution, leading to plantar neuropathic ulceration. Hence, the purpose of this pilot study was to investigate the effect of lower limb joint restriction on mean peak plantar pressure (MPP) and pressure-time integral (PTI) during gait. Methods: Ten healthy, adults were recruited in this study, having no systemic or musculoskeletal conditions which might affect results in this study apart from induced joint restriction. Individuals were instructed to walk barefoot over the Tekscan HR Mat™ system, recording five correct trials. A hip splint was applied to the left hip joint and five correct trials were recorded again. This procedure was repeated whilst restricting the right hip joint. Moreover, the figure-of-eight technique using inelastic bandage was applied to restrict the knee joint and the basket-weave technique using white zinc oxide tape was applied to restrict the ankle joint and five correct trials were recorded per restriction and per limb. Plantar pressure analysis was performed using FootMat™, where MPP and PTI data were obtained from eleven pre-established anatomical locations in the foot [4].

Results & Discussion: A significant increase in MPP and PTI in the first MTPJ was found with hip joint restriction, indicating increased duration during toe-off stage. This suggests the importance of including PTI analysis, since the time spent on a region of the foot might be increasing the risk of ulceration [5].

With knee and ankle joint restriction, MPP in the first MTPJ was significantly reduced, suggesting that a compensatory mechanism might have occurred to improve gait efficiency. The adoption of a hip strategy might have increased hip joint movement, hence decreasing MPP in the first MTPJ [6].

Significantly higher PTI was observed in the contralateral rearfoot regions during hip and knee joint restriction, suggesting that weight is shifted to the contralateral limb during gait, particularly during heel strike, when the ankle joint was not restricted and thus dorsiflexion could occur freely.

Relevance: Results from this study may provide an insight during diabetic lower limb assessment to reduce the risk of tissue breakdown. Since neuropathic ulceration occurs very commonly on the first MTPJ, individuals living with diabetic neuropathy may be further susceptible to mechanical stresses in this region [7]. Resultantly, apart from applying offloading techniques, clinicians should look at the body as a whole unit, including joint kinematic analysis, to reduce the risk of ulceration and amputation.

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The effect of lateral column lengthening on subtalar motion: Are we trading deformity for stiffness?

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Introduction: While lengthening of the lateral column through a calcaneal neck osteotomy is an integral component of flatfoot reconstruction in younger patients with flexible planovalgus deformities, concern exists as to the effect of this intra-articular osteotomy on subtalar motion. The purpose of this study is to quantify the alterations in subtalar motion following lateral column lengthening (LCL).

Methods: The subtalar motion of 14 fresh frozen cadaveric feet was assessed using a three-dimensional motion capture system and materials testing system (MTS). Following potting of the tibia and calcaneus, optic markers were placed into the tibia, calcaneus and talus. The MTS was used to apply a rotational force across the subtalar joint to a torque of 5Nm. Abduction/adduction, supination/pronation, and plantarflexion/dorsiflexion about the talus was recorded. Specimens then underwent LCL via a calcaneal neck osteotomy which was maintained with a 12mm porous titanium wedge. Repeat subtalar motion analysis was performed and compared to pre-LCL motion using a paired t-test.

Results: No statistically significant differences in subtalar abduction/adduction (10.9° vs. 11.8° degrees, p=.48), supination/pronation (3.5° vs. 2.7°, p=.31), or plantarflexion/dorsiflexion (1.6° vs 1.0°, p=.10) were identified following LCL.
Discussion: No significant changes in subtalar motion were observed following lateral column lengthening in this biomechanical cadaveric study.

Relevance: While these findings do not obviate concerns of clinical subtalar stiffness following lateral column lengthening for planovalgus deformity correction, they suggest that diminished postoperative subtalar motion, when it occurs, may be due to soft tissue scarring rather than alterations of joint anatomy.

The effect of prolonged weight bearing physical activities on plantar soft tissue

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Plantar soft tissue plays an important role to attenuate external impact forces acting on the body [1]. As the tissue stiffens, it loses ability to absorb the impact and is more prone to injury. The previous studies on the stiffened plantar soft tissue focused on the diabetes, overlooking healthy people. However, the incidence of tissue injury in non-diseased people is nonnegligible, particularly in those vigorously engaging in physical activities. This study, therefore, investigated the relationship between prolonged weight bearing physical activities and plantar soft tissue properties.

Healthy female participants of early 20s with similar BMI were recruited from engineering(controls) and ballet majors (13 each). Ballet is a typical exercise that apply localized stress on the forefoot, especially 2nd sub-metatarsal head (MTH). (Figure 1) Therefore, the two regions, 2nd sub-MTH where ballerinas frequently apply repetitive load and heel where they don't were measured in this study. Initial thickness of the plantar soft tissue was measured by ultrasound. Peak stress, force and pressure distribution with center of pressure (CP) were obtained from the Zebris® pressure mat in the stance position. The force-displacement curve and stiffness defined in elastic range was recorded using the self-developed indenter [2]. When drawing the force-displacement curve, the composite model that changes linearly () in early phase and otherwise exponentially () was used to find the optimal parameter.

There was no significant difference in the tissue thickness of the MTH and heel between the control and ballet groups. The peak stress of the ballet groups was 14.3% higher in the MTH and 10.7% lower in the heel than the controls. The CP of the ballet was 17% more closer to the neutral axis which means the ballerinas stands more inclined forward from the sagittal plane. Regarding stiffness, there were significant differences in both MTH and heel region. The ballet groups showed significantly higher stiffness in the MTH (p=0.03) and the opposite at the heel (p=0.004). (Figure 2) The parameters of force-displacement curve well explained the behavior of stiffness.

The results of this study quantify the impact of exercise on the properties of plantar soft tissue and confirm that even healthy individuals who do prolonged and repetitive exercise have stiffer plantar soft tissue. The findings in this study can be extended to the making of specialized insoles that can alleviate localized stress for elderly or obese individuals.

Table 1. Tables should be formatted using the "table function" in a word processing program not created with tabs or submitted as graphical items.

	Sex	Age	Number	BMI [kg/m^2]	Average weekly ballet training time
Control	F	21.1 (1.19)*	13	19.6 (1.16)*	None
Ballet	F	20.3 (0.48)*	13	18.7 (1.23)*	11.2 (2.32)*

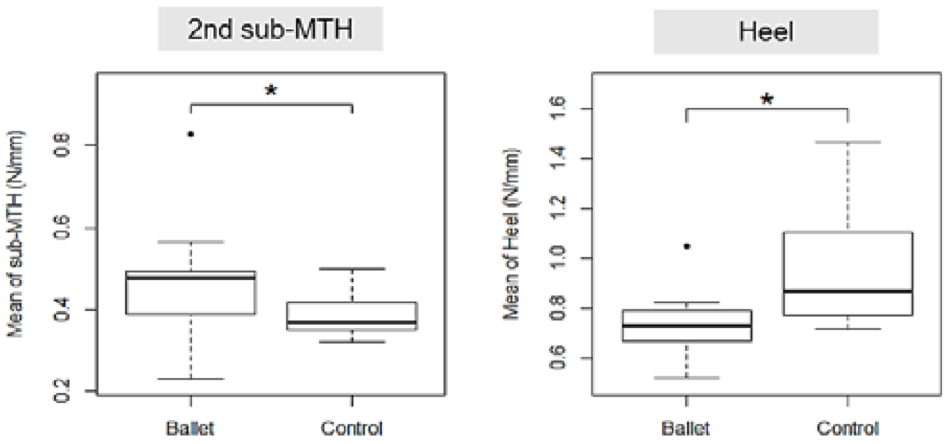
* standard deviation.

Figure 1. The front (A) and side (B) view of relevé, the basic ballet posture that apply excessive load on the 2nd sub-MTH.

(A) Front View

(B) Side View

Figure 2. The stiffness differences between the control and ballet groups in the 2nd sub-MTH (left) and heel (right).



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The efficacy of a diabetic educational program and predictors of compliance of patients with non-insulin dependent diabetes mellitus (type 2)

INTRODUCTION: The aim of this study was to evaluate the efficacy of our educational program for diabetics for patients with diabetes mellitus and to determine the predictors of compliance.

METHODS: A cross-sectional prospective study (June 2005 to March 2017) was performed in a quaternary hospital where patients with diabetes were referred to the outpatient clinic of the diabetic foot group so that they were part of a multidisciplinary group with a specific protocol for guidelines for foot care. The specific guidelines were carried out by the same multidisciplinary team: medical orthopedists specialists in foot and ankle, medical endocrinologists, physiotherapist and nurse.

RESULTS: Out of the 578 diabetic patients, the mean age of was 67 years, 69% being of the female gender. There was 53% made use of insulin to control the disease and the time of disease was 14 years. Obesity was diagnosed by calculation of the body mass index (BMI) and 85% patients were overweight and were obese. Evaluation of protective sensibility showed that 68% were significantly decreased, with sensation as from the 4.0 g monofilament. The presence of ulcers was found in 64 patients. According to the Wagner classification, 57% ulcers had degree 1. The forefoot was the most affected region 63%. Charcot neuroarthropathy was diagnosed in 54 patients. By using the Eichenholz classification, most of the patients 52% were classified as being in phase 3. The assessment of the localization of Charcot arthropathy through the Brodsky anatomic classification most of the lesions 61% were located in the mid-foot. Fifty-three patients had one or more prior amputations at the time of their first appointment, most of the amputations were on toes (66%).

CONCLUSION: The prevention of injuries, with adequate glycemic control and supply of protective shoes is essential.

Level of Evidence II; Therapeutic Studies; Comparative Prospective

Keywords: **educational program, diabetes mellitus,** foot care

The efficacy of surgical treatment in the correction of adult acquired flatfoot deformity: a three-dimensional biometric weightbearing CT evaluation

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Introduction: Multiple surgical techniques are used in the correction of Adult Acquired Flatfoot Deformity (AAFD). Assessment of the efficacy of a surgical treatment in the correction of the deformity is usually performed by clinical evaluation and conventional radiographic imaging. Weightbearing CT (WBCT) allows a more reliable and multiplanar evaluation of AAFD. The Foot and Ankle Offset (FAO) is a WBCT biometric semi-automatic measurement that gauges the relative positioning between the foot tripod and the center of the ankle joint. This study aimed to investigate the efficacy of surgical treatment in correcting AAFD, comparing preoperative and postoperative FAO measurements. We hypothesized that surgical treatment would provide significant correction of the deformity, centering the tripod of the foot underneath the ankle joint.

Methods: In this prospective comparative study, 21 adult patients (22 feet) with flexible AAFD were included, mean age 55 (range, 23-81) years, 13 females and eight males. Patients underwent preoperative and postoperative standing WBCT examination. Three-dimensional coordinates (X, Y and Z planes) of the foot tripod (weightbearing point of the first and fifth metatarsals and calcaneal tuberosity) and center of the ankle (apex of the talar dome) were harvested by two independent and blinded observers. The FAO was automatically calculated from the harvested 3D coordinates by dedicated software. Data regarding the surgical technique used was recorded. Patient Reported Outcomes (PROs) were collected preoperatively and postoperatively at a mean follow-up of 22 (range, 8-36) months. Pre and postoperative FAO measurements were compared by paired T-tests. Multivariate analysis was used to assess the influence of surgical procedures in the amount of FAO correction. P-values of less than 0.05 were considered significant.

Results: We found excellent intra (0.98) and interobserver reliability (0.96) for FAO measurements. The mean preoperative FAO was 10.4 (95% CI, 8.5 to 12.1). There was a significant correction of the deformity postoperatively ($p<0.0001$), with a mean postoperative FAO of 1.4 (CI, -0.1 to 2.9), and mean improvement of 8.9 (95% CI, 6.6 to 11.2). The average increase in PROs was ($p<0.05$): physical function (8; CI, 4 to 12), pain interference (10.3; CI, 4.8 to 15.9), pain intensity (5.3; CI, -10:20.6), mental health (4.2; CI, 0.2:8.2), physical health (4.3; CI, 0.9 to 9.8), and depression (10.4; CI, -0.6 to 21.4). The mean number of surgical procedures performed was 8 (range, 2-12). Spring ligament reconstruction was the only technique that influenced the amount of FAO correction ($P<0.001$).

Discussion: To the author's knowledge, this is the first study to assess the amount of surgical correction of AAFD using standing WBCT images and semiautomatic 3D measurements. We found that surgical treatment provided a significant and pronounced amount of correction in the FAO, with the foot tripod more centered underneath the ankle joint. We also found a significant improvement in the PROMIS after an average postoperative follow-up of 22 months.

Relevance: Among multiple different surgical procedures performed, reconstruction of the spring ligament was the only technique that significantly influenced the amount of FAO correction. Longer-term follow-up studies are needed.

The Diabetic Foot in Remission: Strategies to Make Prevention Pay

DAVID G. ARMSTRONG

Because neuroischemic complications are associated with a high rate of recurrence, we propose a slight shift in the mechanism by which we counsel and communicate risk daily with our patients. If the epidemiology of this problem is comparable with that of cancer, and recurrences are common, then perhaps language commensurate with such risks should follow. After initial healing of an index wound, our unit now refers to patients not as being cured but rather as being "in remission." This concept is easy for the patient and the rest of the team to understand. We believe that it powerfully connotes the necessity for frequent follow-up and rapid intervention for inevitable minor and sometimes major complications. This program will review tried and true as well as upto-the minute advances in biologics, consumer electronics, mechanics, medicine and surgery that are "pushing the envelope" in extending ulcer-free, hospital-free, and activity-rich days in our efforts to make prevention pay.

The foot becomes less spring-like as speed increases

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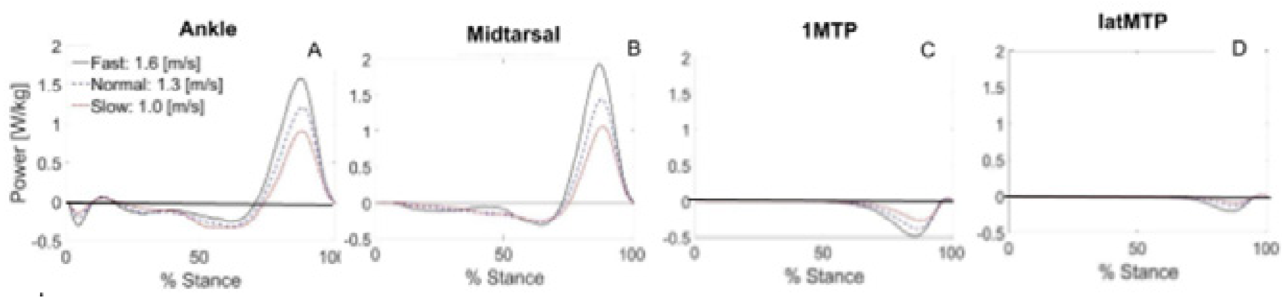
Foot and ankle structures are often considered to act as springs, storing energy in early and mid-stance, and releasing that energy in late stance [1]. Comparing negative and positive work done at a joint may be a way to evaluate a joint's mechanical function, acting like a spring (equal negative and positive work), motor (more positive work), or damper (more negative work) [2]. This technique may help in evaluating joint function changes when varying walking speeds. Additionally, advances in plantar pressure/shear stress measurements [3] could enhance our knowledge of foot and ankle energetics. The purpose of this study was to employ advanced measurement and modeling techniques to evaluate walking speed effects on foot and ankle energetics.

Fourteen healthy participants (1.74±0.10 m, 78.1±17.9 kg) were instructed to walk on a 5.5 m walkway at 1.0 m/s, 1.3 m/s, and 1.6 m/s (±0.02 m/s of target). Researchers adjusted the starting position to prevent targeted foot placement over the pressure/shear device (FootSTEPS, ISSI inc.). Retroreflective markers were adhered to participants' right foot according to a published model [4]. Marker trajectories (Qualisys) were collected at 100 Hz, pressure/shear data at 50 Hz, and reference force data at 1000 Hz. Three trials were collected for each speed and were processed using custom code [5] and Visual 3D. Rigid-body inverse dynamics were calculated for the ankle, midtarsal, 1st metatarsophalangeal (1MTP), and lateral MTP joints (latMTP). Mean power at each joint and speed (Figure 1) were created from participant means and time-normalized to the stance phase of gait.

As speed increased, ankle and midtarsal joints showed mild changes in negative work, with large increases in positive work (Figure 1A, B). In contrast, 1MTP and latMTP joints showed large increases in negative work (Figure 1C, D), with little changes in positive work. Thus, ankle and midtarsal joints became more motor-like while 1MTP and latMTP joints became more damper-like, and all joints became less spring-like with increasing walking speed. The results suggest that the amount of elastic energy returned may be smaller than traditionally thought [6] and may be somewhat independent from walking speed. Additionally, the consistent timing and proportional changes in magnitude of positive midtarsal and negative MTP power profiles suggests kinetic coupling between these two joints, perhaps showing energetic transfer through the windlass mechanism [6]. Future studies could investigate the extent of the spring-like behavior of the foot and ankle as well as coupling amongst foot joints.

Figure 1. Ankle (A), Midtarsal (B), 1st MTP (C), and lateral MTP (D) joint powers [W/kg] versus % stance phase at fast, normal, and slow walking speeds.



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The Foot Core Paradigm: Let's Think Differently about the Foot

Irene S. Davis

Harvard Medical School, Cambridge

The foot is a complex structure with 28 bones, 33 articulations and 20+ intrinsic and extrinsic muscles. Unfortunately, due to this complexity, the foot has been simplified, sometimes as a single unit, in biomechanical models. Clinically, treatment of the foot has been focused on passive approaches such as taping, bracing, and palliative interventions, as opposed to active strengthening. The arch of the foot alone contains 10 intrinsic muscles arranged in 4 layers. These small muscles are critical for the stability of the foot and for normal foot function. This is very much like the role of the stabilizing muscles of the lumbo-pelvic region. Recent studies have shown that chronic support of these foot intrinsic muscles results in their weakening, while removal of chronic support results in their strengthening. The purpose of this presentation is to discuss the importance of the strength and function of foot core muscles and their contribution to healthy foot function. It is hoped that this will provide a greater awareness of how we, as both scientists and clinicians, can better leverage our feet.

The impact of leg dominance on plantar pressure measurements: A STAPP study

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Background: Recent research has shown that leg dominance has an impact on gait [1] and that this impact is significant enough that a leg dominance scores are worth developing [2]. However, it remains unclear how leg dominance impacts plantar pressure measurements. Some studies assume that measurements from opposing feet are identical while others assume that they are completely independent.

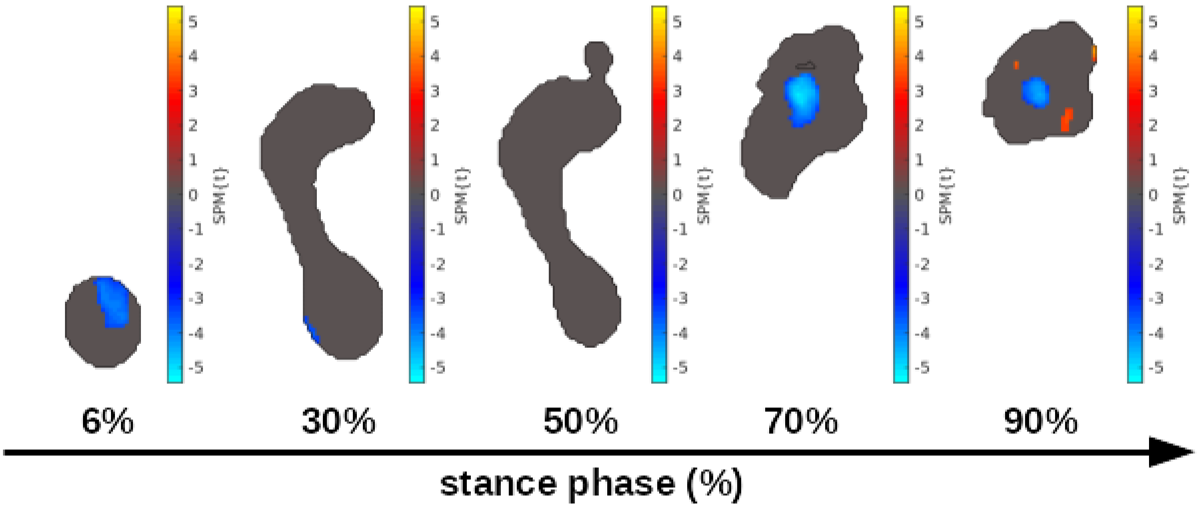
Objective: We aim to determine if leg dominance impacts plantar pressures to a degree that it should be included as a covariate in plantar pressure studies.

Materials & Methods: The CAD WALK healthy controls dataset was used for this study [3] which includes plantar pressure measurements from 55 healthy individuals along with their Waterloo footedness scores [2]. Statistical parametric mapping was performed on the full plantar pressure measurements using STAPP [4]: all measurements were spatially and temporally aligned, then paired t-tests were performed between measurement from the dominant and non-dominant side. Random field theory was then used to correct for multiple comparisons.

Results: Of the 55 subjects, 49 were right-leg dominant (89%) while 6 were left-leg dominant (11%). Figure 1 shows the STAPP results at various points in the stance phase, with blue (red) indicating areas where the dominant side shows significantly less (more) pressure than the non-dominant side. The dominant side showed significantly less pressure at heel strike and under metatarsal 2 during push off.

Discussion: The significant differences between the plantar pressures from dominant and non-dominant feet indicate that leg dominance should be included as a covariate in plantar pressure studies. As STAPP has previously shown greater sensitivity to plantar pressure differences [4], it remains to be seen if these results hold true for other plantar pressure analysis techniques (e.g. peak pressure images, regions of interest).

Figure 1. STAPP results for the effect of leg dominance on plantar pressures



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The influence of calcaneal and first ray osteotomies in the contact pressures of the ankle joint

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Introduction: Medial displacement calcaneal osteotomies (MDCO) and first ray plantarflexion osteotomies, such as a Cotton osteotomy, are frequently used realignment procedures for hindfoot and ankle joint valgus malalignment. Multiple studies demonstrated the effects of calcaneal osteotomies on the contact pressures of the ankle joint (CPAJ), with slight medial displacement of the center of pressure and lateral unloading of the ankle joint. However, the influence of a first ray plantarflexion osteotomy on the CPAJ is yet to be determined. In this cadaveric study, we compared the effects of calcaneal and first ray osteotomies in the CPAJ.

Methods: Fifteen bellow-knee cadaveric specimens were used. Tekscan 5033 sensors were placed in the ankle joint and held with cyanoacrylate. Specimens were loaded in a servohydraulic load frame. Tension loads applied to tendons: Achilles (200N), PTT (40N), peroneals combined (44N), FHL/FDL combined (35N). Specimens were tested in intact position, isolated MDCO (6 and 10mm), isolated Cotton osteotomies (4 and 8mm) and combined MDCO/Cotton osteotomies (10mm and 8mm, respectively). Specimens were then cyclically loaded from 100N-1000N at a rate of 0.5Hz for 30 cycles while CPAJ data was collected at a rate of 20Hz. Average and maximum overall pressure data were extracted as well as the center of pressure (CoP) movement in the anteroposterior (AP) and medial to lateral (ML) directions. Data was also analyzed when divided into lateral, central, and medial areas of the contact pressure map. Groups were compared by the Wilcoxon test. P-values <0.05 were considered significant.

Results: There was a significant ($p<0.05$) and progressive decrease in the average and maximum contact pressures of the ankle joint when comparing intact ankle (1624 and 1964kPa), MDCO (1526 and 1891 kPa), Cotton osteotomy (1370 and 1642 kPa) and combined osteotomies (1292 and 1599 kPa). Cotton (4 and 8mm) and combined osteotomies showed similar contact pressures, that were significantly lower than intact specimens, emphasizing the power of first ray osteotomies in changing the contact pressures of the ankle joint. When accounting for medial, central and lateral aspects of the joint, we found that the decrease in the pressures was only significant in the central (cotton and combined osteotomies) and lateral aspects (combined osteotomy only). No significant differences were found in CoP measurements (both AP ad ML directions).

Discussion: The results of this cadaveric study demonstrate the power of Cotton osteotomies, in isolation or combined with MDCO, in decreasing the overall CPAJ, especially on its central and lateral aspects. MDCO in isolation did not differ from intact specimens in any of the assessments. No significant changes in the center of pressure of the ankle joint were noted following any of the performed osteotomies (combined or isolated).

Relevance: Our findings should guide surgeons when deciding between first ray and calcaneal osteotomies as realignment procedures for hindfoot and ankle valgus deformities, when aiming to unload the lateral aspect of the ankle joint.

Figure 1. The influence of calcaneal and first ray osteotomies in the contact pressures of the ankle joint.

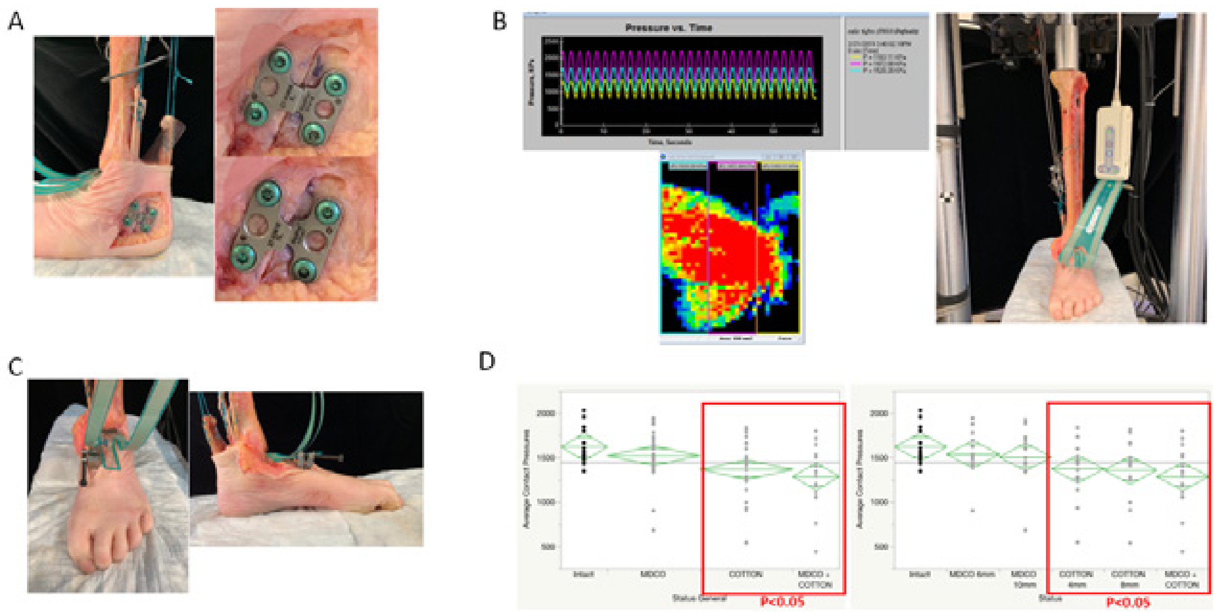

Figure 1. A. Medial displacement calcaneal osteotomy. B. Testing with cyclic loading and pressure map. C. Cotton osteotomy. D. Contact pressures of the ankle joint (average).

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The influence of foot alignment and ankle dorsiflexion range of motion on dynamic lower limb valgus during a classical ballet jump: a cross-sectional study

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Introduction: Classical ballet practice may predispose dancers to the onset of jump-related musculoskeletal injuries due to altered lower limb kinematics [1]. Whereas excessive dynamic lower limb valgus has been associated with overuse [2] and traumatic injuries [3] in classical ballet, the influence of distal factors on this movement pattern is still unknown. This cross-sectional study aimed to investigate whether foot alignment and ankle dorsiflexion range of motion (ROM) predict excessive dynamic lower limb valgus (peak hip adduction and internal rotation and peak knee abduction) during the preparation and landing phases of a classical ballet jump.

Methods: Forty-one healthy amateur female ballet dancers were included. Foot alignment was assessed by the shank-forefoot alignment (SFA) and weight-bearing ankle dorsiflexion ROM was measured by the lunge test. Peak hip and knee angles were analyzed three-dimensionally during the preparation and landing phases of a single-leg jump. A Pearson correlation matrix was used to investigate the association of SFA and ankle dorsiflexion ROM with peak hip adduction and internal rotation and peak knee abduction during the preparation and landing phases of the jump.

Results: There were no associations of SFA and ankle dorsiflexion ROM with peak hip and knee angles during the preparation ($p>0.05$) and landing ($p>0.05$) phases of the jump (Table 1).

Discussion: In classical ballet, distal factors did not predict excessive dynamic lower limb valgus. Given that excessive hip and knee movements are multifactorial, future studies could investigate these relationships in light of a non-linear analysis considering the interaction among predictors.

Relevance: In amateur ballet dancers, a prevention program aiming at correcting foot misalignments and increasing ankle dorsiflexion ROM would not prevent excessive hip and knee movements during the preparation and landing phases of a classical ballet single-leg jump.

Table 1. Pearson correlation coefficients (r) of SFA and ankle dorsiflexion ROM with peak hip and knee kinematics during the preparation and landing phases of the jump.

	Peak Hip Adduction		Peak Hip Internal Rotation		Peak Knee Abduction	
	Preparation	Landing	Preparation	Landing	Preparation	Landing
SFA (degrees)	r = -0.23	r = -0.20	r = -0.16	r = -0.05	r = 0.08	r = 0.24
Ankle Dorsiflexion ROM (degrees)	r = 0.36	r = -0.02	r = 0.08	r = -0.08	r = -0.07	r = -0.07

ROM: range of motion; SFA: shank-forefoot alignment.

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The influence of footwear on lower-limb electromyography in individuals with chronic ankle instability during walking

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Background : Changes in lower limb biomechanics when wearing shoes have been associated with improvement in pain and function in individuals with musculoskeletal pathologies [1, 2]. However, the effects of footwear on the walking biomechanics of individuals with chronic ankle instability (CAI) are still unknown. The objective of this study was to evaluate the lower-limb electromyography (EMG) differences between shod and barefoot walking in individuals with CAI. Quantifying the EMG effects of shoes on these individuals will help clinicians and researchers to better understand their potential benefits in the rehabilitation of this population.

Methods : Twenty-one individuals with CAI walked on a 5-meter walkway shod and barefoot at comfortable (CW) and fast (FW) speeds during which a surface EMG system collected the gluteus medius, vastus lateralis, gastrocnemius lateralis, gastrocnemius medialis, peroneus longus and tibialis anterior muscles activity. EMG data of all muscles were sampled at 1000 Hz and filtered with a 10 to 450 Hz 4th order Butterworth band-pass filter. The Root Mean Square (RMS) of the EMG data was calculated with a 100 ms-moving window. The RMS data of all trials were normalized with the mean peak RMS of the five shod trials at fast walking speed. The shod and barefoot data at CW and FW were compared using a one-dimensional non-parametric mapping analysis. The highest Cohen's d effect size was also calculated for the significant differences.

Results : At CW, tibialis anterior muscle activity was increased from 0 to 2% ($p=0.01$, $d=1.52$) and 5 to 9% ($p=0.01$, $d=1.28$) of the stance phase for shod compared to barefoot walking. At FW, vastus lateralis muscle activity was increased from 0 to 4% ($P=0.02$, $d=1.02$) and decreased from 9 to 16% ($P=0.01$, $d=-1.46$), gastrocnemius medialis muscle activity was increased from 72-78% ($P<0.01$, $d=1.16$) and tibialis anterior muscle activity was increased from 0 to 3% ($P<0.01$, $d=1.41$) and 3 to 14% ($P<0.01$, $d=1.88$) of the stance phase for shod compared to barefoot walking.

Conclusion : The results of this study show that shoes have many lower limb EMG effects during the contact phase of walking and that these change at different walking speeds. The results will help to better target the EMG effects of shoes and inform future efficacy trials aiming to attenuate the deficits associated with CAI during rehabilitation.

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The midfoot joint complex is functionally coordinated with the other lower limb joints for gait forward progression

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Introduction: The midfoot joint complex (MFJC), during the stance phase of gait, has been considered as part of injury and kinetic/energetic mechanisms[1]. However, the MFJC motion may also have a kinematic role in gait forward progression. This study investigated whether the MFJC sagittal kinematics coordinates with the other lower limb joints to produce anterior-posterior position and displacement of the pelvis in walking stance. **Methods:** The kinematics of 11 able-bodied adults was assessed during ten stance phases of walking. Pelvic anterior-posterior position was modeled as a function of the angular positions of the forefoot-ground ("ball" of the foot), rearfoot-ground, MFJC, ankle, knee, and hip joints, measured during stance. Joints' contributions to pelvic linear position were expressed as the pelvic position produced by each joint angle, computed using partial derivatives in the model's equation. The addition of all joints' contributions at each time instant represented the instantaneous pelvic linear position. Model validity was checked by comparing the curves of measured and model-estimated pelvic position, for each trial, using the Coefficient of Multiple Determination (CMD). The total contribution of each joint to pelvic displacement (outcome 1) was computed as the sum of the absolute differentials of the joint contribution to pelvic position. To investigate whether the MFJC coordinates with the other joints, it was tested if between-trials variations in MFJC contributions to pelvic position are functionally compensated by opposite variations in the summed contributions of the other joints, in a way that reproduces pelvic positions across trials. At each time instant, the presence of functional compensation (outcome 2) was defined as the presence of large negative covariance (Pearson□-0.7) of each joint contribution with the summed contributions of all the other joints. **Results:** Model validity was high (average CMD 0.95 (SD 0.04); $p<0.001$) and pelvic positions were fairly reproduced across trials (average RMSE 0.013 m (SD 0.0038)), which allowed the outcomes to be considered: (1) The MFJC had the third largest contribution to pelvic displacement (Table 1) and (2) was the joint that participated longer in functional compensations (when covariance □-0.7) (Table 2). **Discussion:** The MFJC motion influences gait forward progression and is functionally coordinated with the other lower limb joints. Regulation of joints' motion by the motor system seems to involve the MFJC. **Relevance:** Revealing MFJC functional coupling with other joints may help understand patterns of movement compensations involving abnormal foot motion and their possible connections to clinical conditions.

Table 1. Mean values (standard deviation) of the total contributions to pelvic linear displacement.

Joint	Total contribution (m)	Total contribution (%)
Forefoot-ground	1.34 (0.21)	30.87
Rearfoot-ground	0.59 (0.19)	13.59
MFJC	0.78 (0.30)	17.83
Ankle	0.80 (0.01)	18.48
Knee	0.65 (0.09)	14.84
Hip	0.19 (0.01)	4.38

Table 2. Duration of participation of the joints in the between-trials' functional compensations.

FF-ground (%)	RF-ground (%)	MFJC (%)	Ankle (%)	Knee (%)	Hip (%)
44.81 (21.0)	12.63 (1.34)	69.45 (19.55)	67.36 (22.35)	59.72 (24.8)	17.0 (15.7)

% of stance duration. FF: forefoot. RF: rearfoot.

Reference:
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The Number of Trials Required to Estimate a Representative Foot Loading Pattern

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INTRODUCTION: When reporting plantar pressure distribution, it is important to ensure that the estimates reflect the subject's typical foot loading pattern. Previous research used the intra-class correlation coefficient and sequential averaging analysis to estimate accuracy and reproducibility, however, those methods are more relevant for discrete points rather than the continuous waveforms seen in dynamic foot loading [1]. Currently, there is no valid approach for determining how the number of trials affects the accuracy of the estimate of a subject's typical foot loading pattern. The goal of this study was to develop a more robust method for determining the number steps necessary to achieve a given accuracy in estimating the typical foot loading pattern on four different walking surfaces.
METHODS: 70 healthy subjects (41 F, 29 M; 43.918.2 years, 7112.6 Kg) were provided the same model shoes and asked to walk at a self-selected speed on four different surfaces: treadmill, outdoor pavement, outdoor grass, and lab walkway. Overall planar force during each step was calculated from pressure recordings (Pedar, 100 Hz) and normalized to body weight (BW) after removing steps immediately before, during and after turnarounds. Using a recently developed method for the construction of confidence bands for waveforms, we developed a new measure of margin of error for waveforms that describes the entire waveform falling within 95% confidence bounds [2]. This margin of error was then used to estimate the number of steps required per surface.
RESULTS: An average of 310 to 597 steps were included in the analysis for each of 140 feet over the 4 surfaces (Table 1). Foot loading variability was highest during midstance (Figure 1). Laboratory walking exhibited the widest confidence band and required the most steps to estimate an accurate waveform, while treadmill and pavement surfaces required the fewest steps to estimate typical waveforms within a reasonable margin of error (Table 2, Figure 2).
DISCUSSION: This study is the first to develop an objective approach to quantify the number of steps necessary to achieve an accurate estimation of plantar pressure distribution while considering the waveform nature of foot loading data. Despite the risk of presenting inaccurate results, few studies substantiate the number of trials or steps with empirical evidence. Laboratory-based studies performed with relatively short walkways require the most steps to accurately estimate the typical loading pattern. These results may serve as a guide for future experimental designs to yield more robust results.

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IMAGES AND TABLES:

Table 1: Number of steps collected by surface.

	Steps (average)	Range
Grass	405±68	125 to 527
Laboratory	310±70	143 to 428
Pavement	597±64	404 to 718
Treadmill	508±90	49 to 618

Table 2: Number of steps required to achieve the corresponding margin of error.

Target Margin of Error	Grass	Laboratory	Pavement	Treadmill
1.0 % Bodyweight (BW)	4247	5305	1795	1785
2.5% BW	680	849	288	286
5.0% BW	170	213	72	72
10.0% BW	43	54	18	18
15.0% BW	19	24	8	8
20.0% BW	11	13	5	5
30.0% BW	5	6	2	2

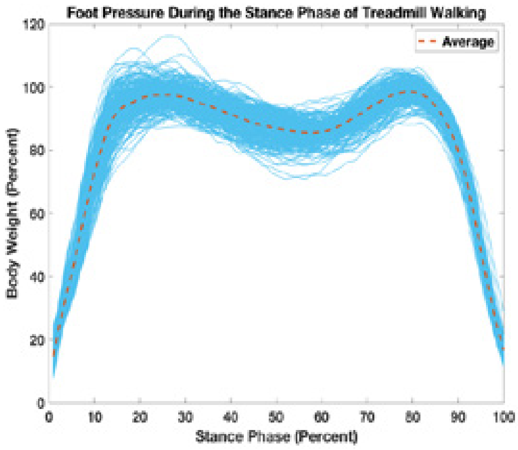


Figure 1: Total plantar force during 286 steps of treadmill walking for one subject. Blue lines indicate individual steps and the red dashed line is the average.

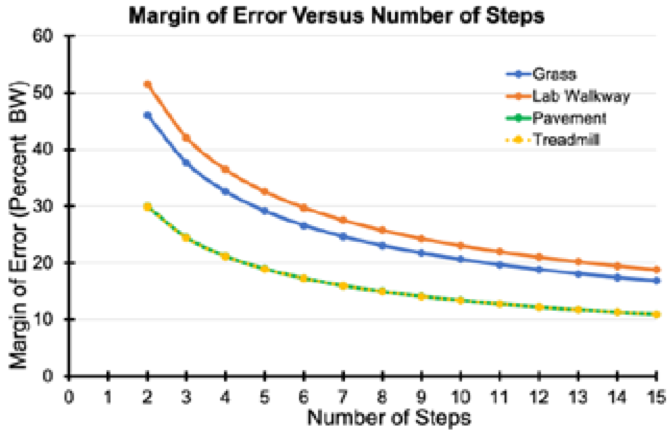


Figure 2: Changes in the margin of error in estimating the typical plantar force waveform with increasing number of steps over the four walking surfaces. Pavement and treadmill are nearly identical.

The Ponseti method in children with clubfoot after walking age – systematic review and metanalysis of observational studies

Background: The prevalence of untreated congenital clubfoot among children older than walking age is higher in developing countries due to limited resources for early care after birth. The Ponseti method represents an intervention option for older, untreated children.

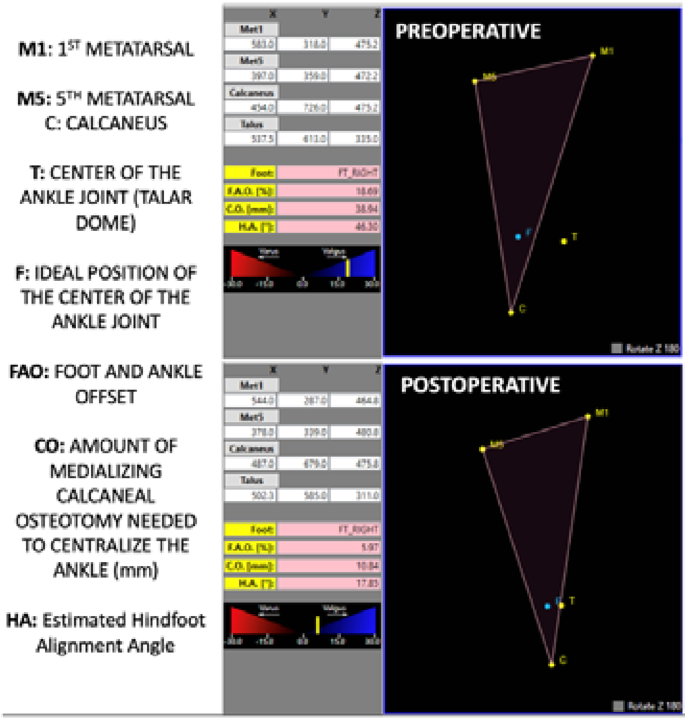
Methods: A metanalysis was conducted of observational studies selected through a systematic review of articles included in electronic databases (Medline, Scopus, Embase, Lilacs, and the Cochrane Library) until June 2017. A pooling analysis of proportions with 95% confidence intervals (CIs) and a publication bias assessment were performed as routine. Estimates of success, recurrence, and complication rates were weighted and pooled using the random effects model.

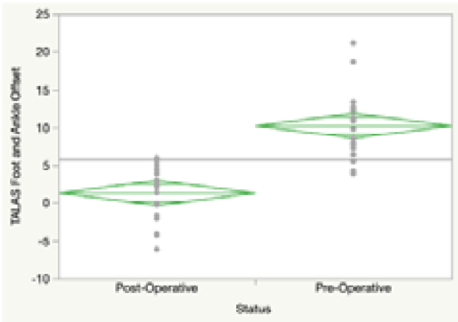
Results: Twelve studies, including 654 feet diagnosed with congenital clubfoot in children older than walking age (older than 1 year old), were included for analysis. The rate of satisfactory outcomes found via a cluster metanalysis of proportions using the random effects model was 89% (95% CI = 0.82-0.94, $p < 0.01$), relative to the total analysed. The recurrence rate was 18% (95% CI = 0.14-0.24, $p = 0.015$), and the rate of casting complications was 7% (95% CI = 0.03-0.15, $p = 0.19$).

Conclusion: Application of the Ponseti method in children with untreated idiopathic clubfoot older than walking age leads to satisfactory outcomes, has a low cost, and avoids surgical procedures likely to cause complications. The results obtained exhibited considerable heterogeneity.

LEVEL OF EVIDENCE: Level I: High-quality, metanalysis
Key words: congenital clubfoot, foot, congenital deformities of the foot, review, child.

Figure 1. The power of surgical treatment in the correction of adult acquired flatfoot deformity: a three-dimensional biometric weightbearing CT evaluation





	Mean	Std Error	Lower 95% Confidence Interval	Upper 95% Confidence Interval
Post-Operative	1.4032	0.81169	-0.235	3.041
Pre-Operative	10.2745	0.81169	8.636	11.913

Difference	8.8714
Std Err Dif	1.1479
Upper CL Dif	11.1879
Lower CL Dif	6.5548
Confidence	0.95
P-Value	<.0001*

The rotational positioning of the bones in the medial column of the foot: a weightbearing CT analysis

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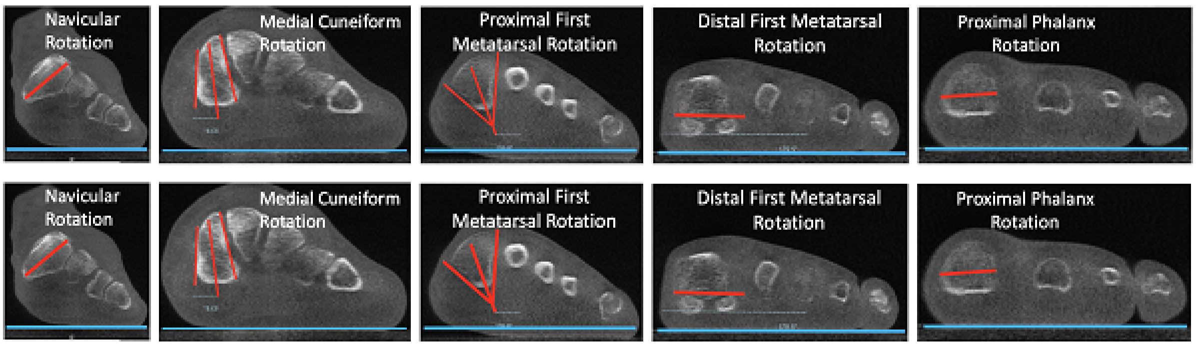
Introduction: Instability of the medial column (navicular, medial cuneiform, first metatarsal, hallux) plays an important role in the development of multiple pathologies, including adult acquired flatfoot and hallux valgus deformities [1,2]. Despite this significance, the typical rotational pattern of each bone of the medial column is not fully understood [3,4]. The objective of this study was to evaluate the rotational position of these bones using three-dimensional weight-bearing CT (WBCT) images to serve as a reference for future studies.
Methods: A retrospective review was conducted for 95 patient (110 feet) who underwent WBCT assessment of various foot disorders. WBCT scans were performed used a cone-beam CT extremity scanner (PedCAT CurveBeam) and evaluated using dedicated software (CubeVue, CurveBeam). One fellowship trained Orthopedic Foot and Ankle Surgeon performed the angular measurements to assess the rotational axis of each bone in the coronal plane axis in relation to the floor (Figure 1). As standard, we defined supination as negative values and pronation as positive values.
Results: All bones of the medial column were found to have an average rotational alignment in pronation (internal rotation) (Figure 2). The mean value and 95% Confidence Interval (CI) for the rotational positioning of each bone was: navicular, 43.2° (CI, 41.1 to 45.3); medial cuneiform, 6.1° (CI, 4.0 to 8.3°); proximal first metatarsal, 33.9° (CI, 31.8 to 36.0°); distal first metatarsal 18.5° (CI, 16.4 to 20.6°); and proximal first phalanx 21.6° (CI, 19.5 to 23.7°) (Table 1).
Discussion: We found that all bones demonstrate some degree of pronation. The pronation is most pronounced in the navicular bone and is minimal in the medial cuneiform. The first metatarsal specifically demonstrates an intrinsic relative supination, from proximal to distal, of about 15°. Our data can serve as reference values for future comparative, controlled and prospective studies.
Relevance: This is the first study that attempts to quantify the rotational profile of the bones of the medial column of the foot.

Figure 1. Rotational axes for each measured bone segment



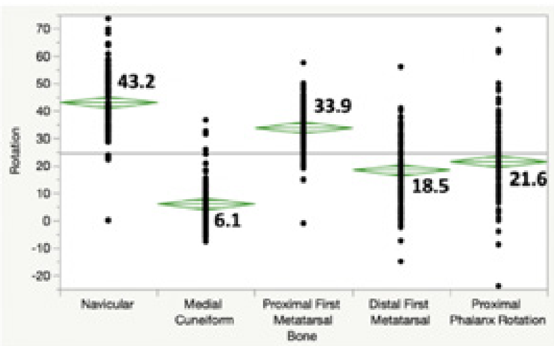


Figure 2. All rotational measurements with mean rotation

Rotational Profile Medial Column (°)	Number	Mean	Lower 95%	Upper 95%
Navicular	110	43.1615	41.058	45.265
Medial Cuneiform	110	6.1491	4.045	8.253
Proximal First Metatarsal	110	33.9068	31.803	36.011
Distal First Metatarsal	110	18.4973	16.393	20.601
Proximal Phalanx	110	21.6055	19.502	23.709

Table 1. Mean values, 95% Confidence Interval

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The use of three-dimensional (3D) biometric measurements to predict ddditional alignment procedures in total ankle replacement

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Introduction: Preoperative evaluation of ankle and hindfoot deformities in patients undergoing total ankle replacement (TAR) is challenging. Characterizing deformity based on conventional radiographs is limited by its two-dimensional (2D) nature and is influenced by anatomical and operator-related bias. The final decision to perform associated corrective alignment procedures, that include calcaneal osteotomies, midfoot and forefoot osteotomies/fusions, and soft tissue balancing, is made intraoperatively, following insertion of the TAR components. The use of weightbearing cone beam CT (WB CBCT) images and three-dimensional (3D) biometric tools, encompassing the hindfoot alignment, foot tripod, and center of the ankle joint, may be an effective surgical planning instrument. In this retrospective study, we assessed the ability of these tools to predict additional procedures performed at the time of TAR.

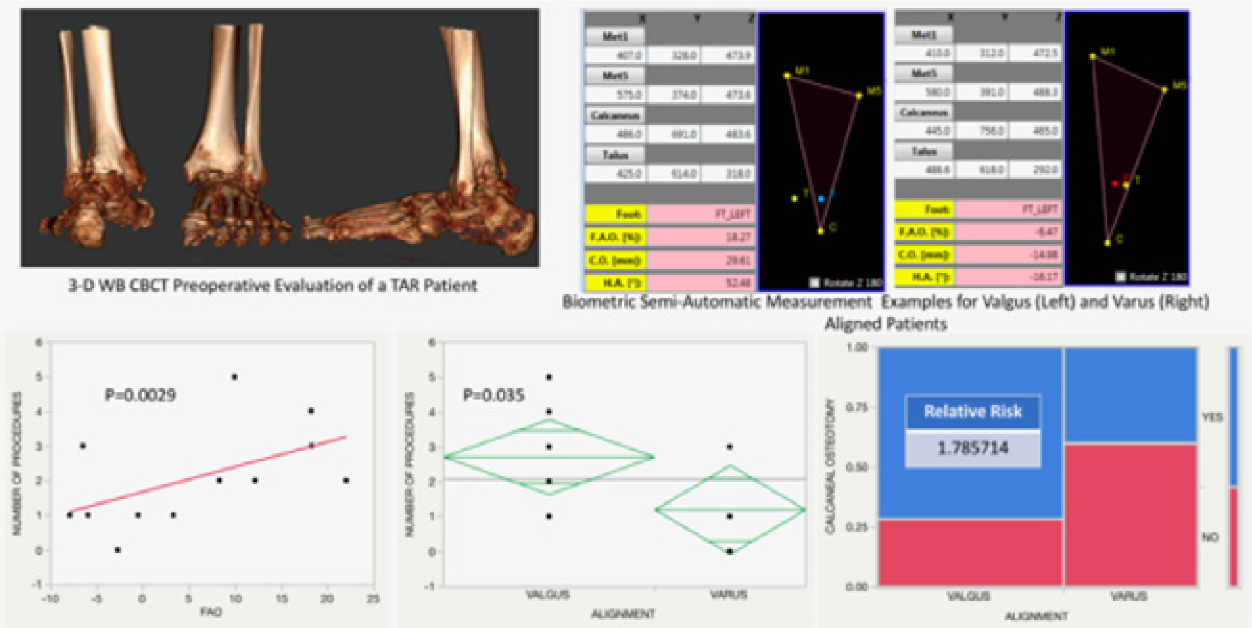
Methods: In this retrospective study, we enrolled 22 patients that underwent TAR and had preoperative WB CBCT studies. We excluded seven patients with isolated ankle CBCT images and three with metallic hindfoot implants. Patients demographics, type and number of additional alignment procedures were noted. The WB CBCT data sets were screened using a built-in semi-automatic measurement software. 3D coordinates (x/y/z) were collected for specific anatomical landmarks required for the software to calculate Foot and Ankle Offset (FAO), that includes the WB points of the first, fifth metatarsal heads and calcaneus, as well as the highest talar dome point. FAO is a representation of the torque (offset) between the hindfoot/forefoot midline and the center of the talus and is given as a percentage of foot-length. Patients were then divided into varus and valgus hindfoot alignment groups accordingly to their measured FAO, using available literature FAO values for normally aligned feet (2.3%, ±2.9%).

Results: We included 12 patients (6F/6M), mean age 65 (range, 47-80). The mean preoperative FAO was 5.73 (CI -0.99 - 12.55). Seven patients had valgus and 5 patients had varus alignment of the hindfoot. The mean number of additional procedures performed was two (range, 0 to 5), and included: calcaneal osteotomy (58%), Achilles tendon lengthening/Gastroc recession (58%), Cotton osteotomy (25%), First TMT fusion (17%), talonavicular fusion, naviculo-cuneiform fusion, Brostrom procedure (8%). The FAO was found to positively correlate with occurrence of additional alignment procedures ($p=0.003$). Patients with valgus hindfoot alignment had significantly increased number of additional procedures (2.7; CI 1.6 – 3.8) when compared to varus alignment (1.2; CI -0.1 – 2.5) ($p=0.03$) and were found to have 1.8 times more chances to have a calcaneal osteotomy.

Discussion: This is the first study to evaluate the role of 3D biometric tools and semi-automatic WB CBCT measurements in the preoperative assessment of foot alignment in patients undergoing TAR. We found that increased Foot and Ankle Offset (FAO) significantly predict the occurrence and the number of additional alignment procedures, including calcaneal osteotomies.

Relevance: We believe that the use of biometrics and semi-automatic measurements, that accounts for the relationship between center of the ankle and tripod of the foot, may enhance the preoperative assessment, surgical planning and outcomes of TAR patients. Prospective and postoperative studies demonstrating correction are needed.

Figure 1. The use of three-dimensional (3D) biometric measurements to predict additional alignment procedures in total ankle replacement



There is no difference between 2 and 5 minutes of static stretching on the mechanical properties of the Achilles tendon

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Introduction: Stretching is widely used to increase the range of motion (ROM) [1]. However, the stretching effects on the tendon mechanical properties are not clear [2,3]. We aimed to verify the effects of a six-week program of passive static stretching, using two different stretching periods, in the ankle ROM and in the Achilles tendon passive mechanical properties. **Methods:** Thirty adults were divided into three groups: (CG) control group (n=10; 23.8±3.73 years); (G2) 2-minute stretching group (n=10; 22.6±3.02 years) and (G5) 5-minute stretching group (n=10; 24.9±6.44 years). Stretching was applied with a frequency of 3 times a week, for 6 weeks. The outcomes (ROM, tendon, musculotendinous and muscle stiffness, myotendinous junction displacement, passive torque, isometric maximal voluntary contraction, hysteresis, tendon cross-sectional area) were evaluated before, after and at two weeks of follow-up after the end of the intervention. **Results:** ROM increased in G2 after 6 weeks (p=0.006), and this increase was maintained at the follow-up (p=0.001). The CG's ROM also increased after six weeks (p=0.009), but was not maintained at follow-up. There was no ROM change in G5 in any of the tests. Tendon stiffness did not change after training or follow-up in any group. The musculotendinous stiffness decreased in G5 at the follow-up (p=0.019), with no difference in the CG and G2. Muscle stiffness increased in CG and G2 at the follow-up (p=0.004 and p=0.001, respectively), with no change in G5. The myotendinous junction displacement decreased in G2 at the follow-up (p=0.028), remaining unchanged in CG and G5. The passive torque increased in CG and G2 at the follow-up (p=0.004 and p=0.001, respectively), with no difference in the G5. The isometric maximal voluntary contraction, hysteresis and tendon cross-sectional area did not change post-intervention and at follow up in all three groups. **Discussion:** Despite the groups' similarity in several outcomes, the 2-minute passive static stretching protocol increased the ankle ROM, with muscle stiffness, myotendinous junction displacement and passive torque changes being observed after two weeks with no stretching intervention. **Relevance**: It is suggested that a shorter stretching exposure may be better than the long 5-minute of passive stretching protocol for muscle-tendon-joint adaptation.
ReBEC Registration: RBR-5J3H3C

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Towards a cyclic model of human gait

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The inverted pendulum model of gait is perfectly efficient in theory, but underperforms in practice, with empirical evidence indicating that human gait achieves only a fraction of the predicted energetic efficiency. The main cause of the discrepancy has been linked to the need to redirect the body's mass from leg to leg between steps, which requires a significant amount of work during the transfer [1]. This article lays the conceptual groundwork for a more efficient model of human gait, in which forward motion is produced by the application of lateral force by the foot (Figure 1) – eliminating the costly vertical components of conventional gait – and the transfer of mass is avoided as the legs cycle symmetrically beneath the vertically and mediolaterally static center of mass. To achieve these improvements, the new model of gait reconceives the feet as dynamic, three-dimensional spiral structures that rotate around a central axis when they do work (Figure 2). A set of targeted exercises is proposed to transition feet developed under the conventional model of biomechanics to this "spiral model" (Figure 3). Results from application of these exercises over a five-year period are presented.

Figure 1. Placement and motion of the right foot through a single stance phase. Application of lateral force by the foot's outer edge rotates the foot around its longitudinal axis, driving the swing hip in an arc around the body's midline to position the swing foot for the next step.

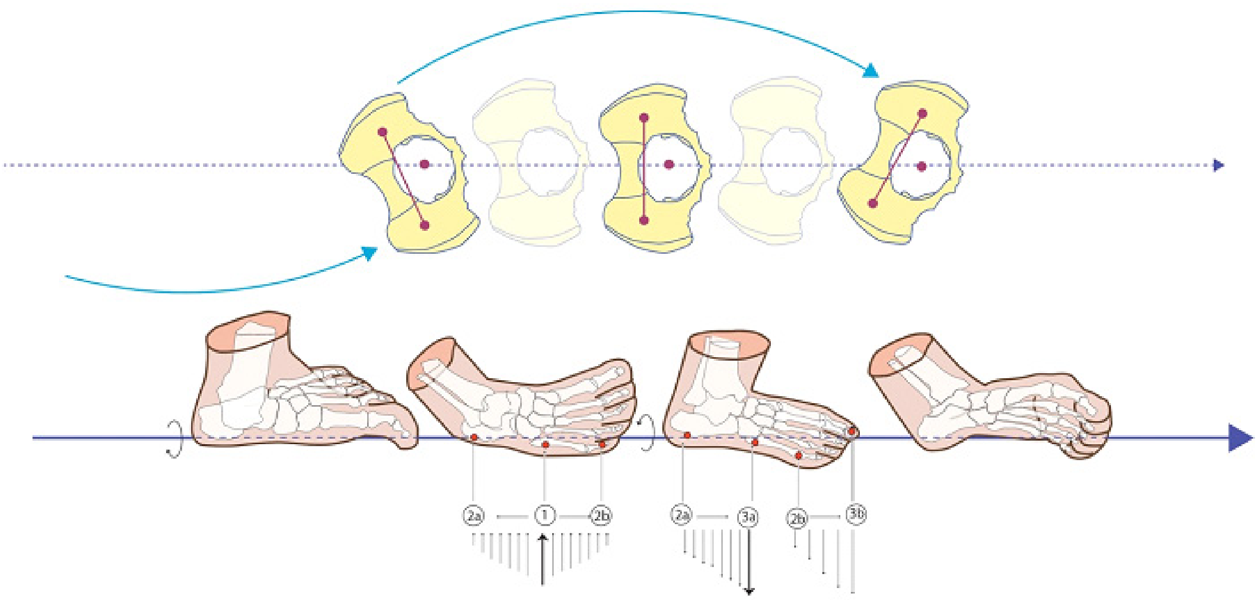


Figure 2. Logarithmic spiral and rotational axis of the foot. (a) three-dimensional form of logarithmic spiral. (b) View of the foot emphasizing vertical structure of the spiral across the transverse arch with corresponding log spiral. (c) Rear view of the foot emphasizing spiral form.

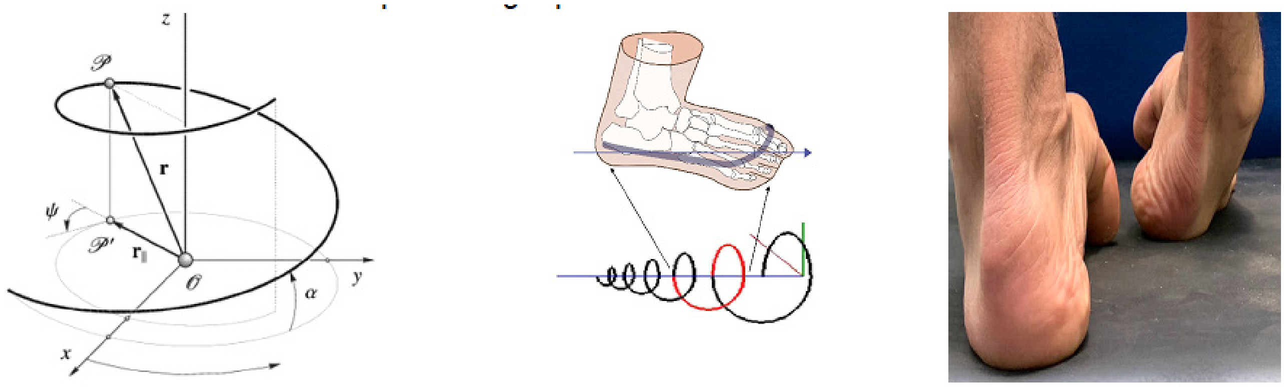
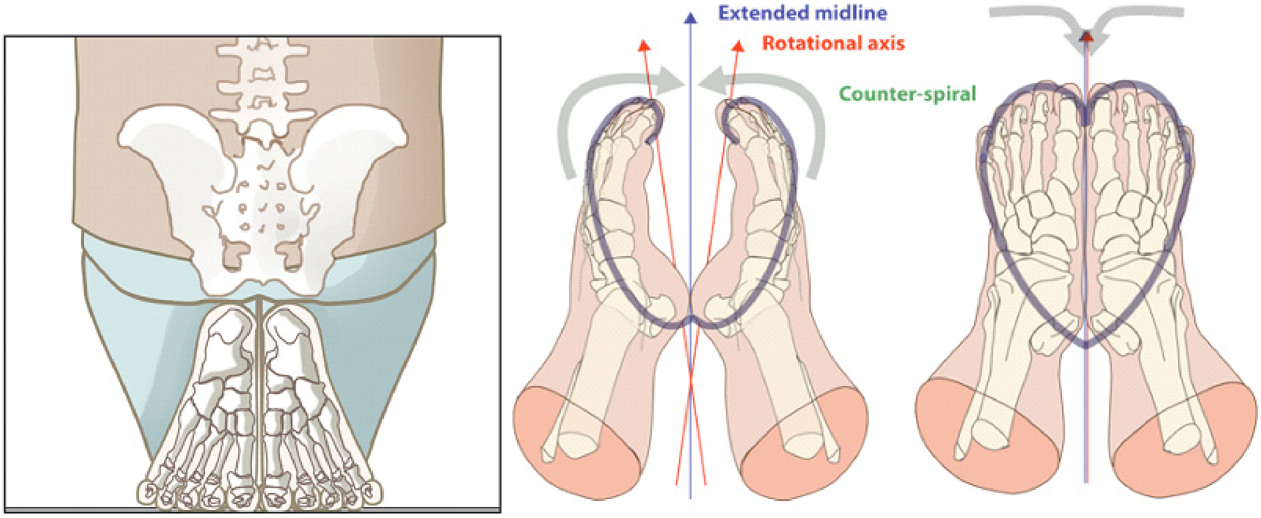


Figure 3. Counterspiral mechanism. The clenched and inverted feet are rotated against each other at the midline under controlled application of the body's weight, activating a symmetry-based development engine that slowly realigns the bones of the feet into their spiral structures and then stretches muscle and connective tissue over the resulting framework, "winding" the lower body.



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Treatment Of Diabetic Foot With Ozone Therapy

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INTRODUCTION: The objective is to analyze in scientific publications the benefits that the treatment of this pathology with ozone brings to healing of ulcers in patients with Diabetes mellitus (DM). **METHODOLOGY:** This is a literature review. For the search we used the databases: Scielo, Google Academic and PubMed. The keywords 'Neuropatia Periférica', 'Diabetes Mellitus', 'Úlcera do Pé Diabético', 'Cicatrização de Feridas', 'Ozonização' e 'Estresse oxidativo', defined with the help of the "Descritores em ciências da saúde (DeCS)". A bibliographic research was conducted in the period from 2015 to 2020, in Portuguese, English and Spanish, with specific methodology for original articles (N = 7), review articles (N = 4), case reports (N=1), guidelines (N = 2) and monographs (N = 2). A total of 16 articles were analyzed, 56.25% addressing treatment, 18.75% prevention, 12.5% treatment and prevention and 12.5% definition. **RESULTS:** It was demonstrated that there is a great incidence of DM cases that evolve to diabetic foot ulcers, which can cause amputations, altering the quality of life, increasing the time of hospital treatment and the mortality rate by peripheral neuropathies. It was observed that conventional treatments are not capable of acting effectively under the proliferation of resistant bacteria. In contrast, the use of ozone therapy increases blood flow and tissue oxygenation by decreasing platelet aggregation and increasing the flexibility of erythrocytes, which facilitates their passage through the capillary vessels. In addition, the use of ozone promotes the formation of reactive molecules of oxygen, which inhibits bacterial, fungicidal and microbial growth and stimulates the release of the growth factor (TGF-β1), which performs the repair of the tissue. Thus, there is an acceleration of the wound healing process and a decrease of the patient's hospitalization time. **CONCLUSION:** Given current growing research on ozone therapy and the positive results obtained, ozone therapy is concluded to be an efficient and economically viable joint method of conventional therapy, already used for the treatment of diabetic foot. **CLINICAL RELEVANCE:** Ozone therapy is a safe and effective procedure in tissue repair, having antimicrobial, bactericidal and fungicidal effects that prevent complications and speeds up the healing process. **KEYWORDS:** Foot Ulcer, Diabetic; Diabetes Mellitus; Ozonation; Oxidative Stress; Wound Healing.

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Twelve weeks of eccentric training do not improve calf muscle isometric torque after Achilles tendon rupture

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Introduction: Achilles tendon (AT) rupture is associated with deleterious calf muscle adaptation that leads to an ineffective triceps-surae muscle function [1]. Eccentric contractions have been shown to improve calf muscle neuromuscular properties in healthy people [2-3]. However, there is a lack of studies showing the eccentric training effects in AT rupture rehabilitation. The aim of our study was verifying the effects of a 12-week submaximal eccentric training on triceps-surae muscle torque in patients subjected to AT surgical repair. **Methods**: Twenty volunteers participated in this study approved by the University Ethics Committee (#96310118.4.0000.5347). Participants were randomized in two groups: (1) isokinetic group that trained on the isokinetic dynamometer (38.6±7 years old and 4±5 years of injury) or (2) traditional group that trained at the gym with a specific stand-up plantar flexor machine (38.1±4 years old and 4±4 years of injury). All participants were submitted to a 12-week submaximal (60-80% of the max) eccentric training for the plantar flexor muscles. Participants were evaluated at four moments: at baseline; after 4, 8 and 12 weeks of training. Torque was obtained from maximum voluntary isometric contractions, performed on an isokinetic dynamometer at 30°, 10°, 0° (neutral) and -10° of plantar flexion. A three-way ANOVA with Bonferroni's correction was used to verify effects and interactions for group, leg and joint angles. Significance level was set at 0.05. **Results:** Torque was higher at the healthy compared to the injured leg for all moments and angles ($p<0.05$). However, only at -10° and 0° ($p<0.05$) there was a training effect at the healthy leg that was higher in post-8 ($p=0.009$) and post-12 ($p=0.028$) compared to baseline. Isokinetic group was higher only at 30° of plantar flexion for all moments ($p=0.029$). **Discussion:** Although a recent study [3] showed that twelve weeks of maximal eccentric training improved the plantar flexors' neuromuscular properties, our preliminary results showed no improvement in AT rupture reconstruction patients. Patients presented AT deficits even 7 years post-surgical reconstruction [4], but we show that 12 weeks of submaximal training may not be enough for strength improvement. **Relevance:** A longer training period might be necessary to produce the desired triceps-surae strength improvement in AT patients. Defining this optimal period is utterly important for physiotherapists and trainers when prescribing strength training for this population. Trainings with high load can also be a solution but need to be tested.

Trial registration: Clinical Trials (#NCT03861572)

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Two weeks of anterior to posterior talocrural joint mobilizations do not change dorsiflexion at heel strike in those with chronic ankle instability

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Introduction: Lateral ankle sprains are highly prevalent in the United States and can lead to chronic ankle instability (CAI), a condition characterized by repeated episodes of ankle giving way and persistent pain and disability.[1] Those with CAI are known to have decreased dorsiflexion around heel strike during gait[2], which increases the risk of future ankle sprains[3]. Two-weeks of anterior to posterior talocrural joint mobilizations (JM) are known to improve range of motion, balance, and patient reported functional outcomes,[4 5] however, their effects on gait biomechanics are unknown. The purpose of this investigation was to determine the impact of a two week joint mobilization intervention on dorsiflexion position around heel strike.

Methods: Participants with CAI were identified with the Ankle Instability Instrument (AII), the Foot and Ankle Ability Measure Activities of Daily Living Subscale (FAAM-ADL) and Sport Subscale (FAAM-S) (n=20, age: 21.90±3.96 yrs, height: 167.64±8.91 cm, weight: 66.96±10.74 kg, No. ankle sprains: 4.25±2.36, AII: 7.40±1.47, FAAM-ADL: 79.36±9.04%, FAAM-S: 65.49±10.68%). All participants received six sessions of grade III, open chain anterior to posterior talar JM to their involved ankle within a two week period. Each treatment consisted of 2 minutes of JM, 1 one minute of rest, and another 2 minutes of JM. Sagittal plane ankle position during over ground walking was collected at 120 Hz before and after the six treatments using Vicon Nexus 2 (Vicon, Oxford, UK). Paired t tests were conducted between pre and post scores for three time points: 300 ms before heel strike, at heel strike, and 300 ms after heel strike.

Results: There were no significant differences in dorsiflexion position after a two week joint mobilization treatment at any time point: (300 ms pre: mean difference(MD): 0.08°, p=0.96, 95% confidence interval (CI) (-2.43°, 2.59°), at heel strike: MD: -0.57°, p=0.71, 95% CI: (-3.11°, 1.97°), 300 ms post: MD: -1.26°, p=0.35, 95% CI (-3.51°, 1.00°).

Discussion/ Relevance: While JM are an important tool to address multiple CAI related impairments, they do not improve dorsiflexion during gait in those with CAI. These results are consistent with literature on strength training, taping/ bracing, and balance training intervention strategies in those with CAI. Future research should identify other treatments that modify dorsiflexion around heel strike to decrease the risk of subsequent lateral ankle sprains.

This project was supported by the National Center for Complementary and Integrated Health (NCCIH), project 1R21AT009704-01.

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Type II diabetes and peripheral neuropathy in older adults postural sway outcomes: Nintendo Wii balance board as a clinical tool.

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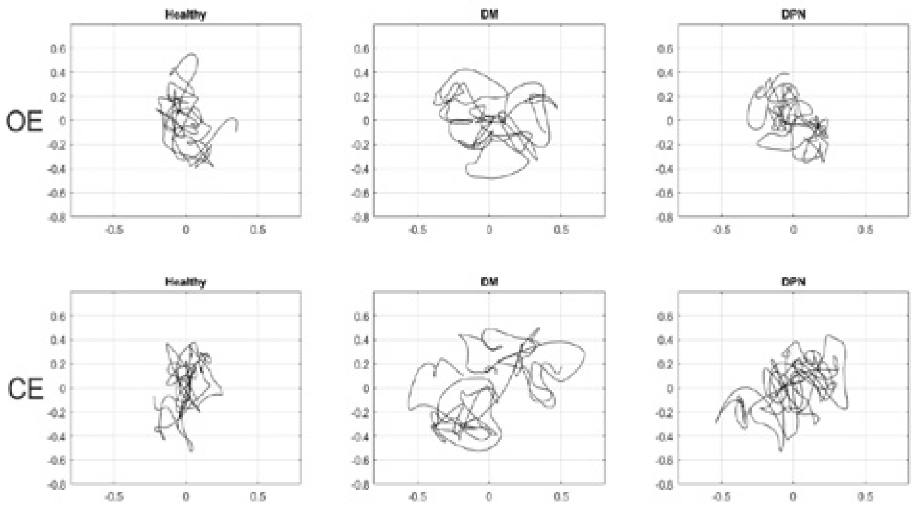
Introduction: The diabetic neuropathy is one of the main causes of hospitalization and amputations in diabetics worldwide. [1] Its etiology is multifactorial, however, it is mainly associated with the presence of peripheral neuropathy(DPN) which compromises distal sensitivity and other complex functions such as body balance.[2]. In these context, falling is more common in older adults with type 2 diabetes (DM) and can be related to the presence of DPN. [3]. The early recognition of balance loss related to DPN can be challenging, and Nintendo Wii balance board (WBB) has been proposed has a valid low cost method for these purpose [4]. The aim of this study was to evaluate the differences in postural sway in older adults with diabetes and DPN in different static balance conditions.
Method: 30 subjects between 55 and 70 years (10 healthy, 10 with DM and 10 with DM and DPN) were selected based on inclusion and exclusion criteria. Data from WBB was collected in three conditions with open and closed eyes (dual task, firm and unstable surface). Signal pre-processing, consisting in SWARII algorithm, was implemented for minimizing sampling frequency irregularities from WBB[5]. Static balance outcomes from center of pressure (COP) behavior was obtained using linear and no-linear metrics.
Results: Significant differences were found in 95% confidence ellipse COP area, between healthy subjects and DPN in closed eyes condition(p=0,03) and between healthy participants and DM in closed eyes unstable surface conditions(Fig.1). Differences were also observed between diabetic conditions in dual task with closed eyes(CEDT) (p=0,01). Sample Entropy(*SampEn*) for medio-lateral and antero-posterior COP displacement showed significant differences (p=0,02) between healthy subjects and DPN in open eyes unstable surface conditions. The main effect between DM and DPN participants, was found in CEDT *SampEn* data (p=0,008).
Discussion: COP sway analysis using WBB allows to differentiate healthy older people from diabetics with and without clinically diagnosed peripheral neuropathy. Our results are consistent with data from studies where WBB was used to assess static balance in elderly population with DM[6].These low-cost method can be useful to assessing the efficacy of sensorimotor training in diabetic neuropathy patients in clinical environments where low precision is acceptable.[7]

Figure 1. Healthy and DM/DPN older adults COP displacement(cm) pathways during 30 seconds of static balance task with open(OE) and closed eyes condition(CE) in unstable surface.



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Use of dynamic tape in the control of excessive pronation movement

The association of several dysfunctions with excessive joint pronation (SILVA, R et al 2014., CHEUNG, T et al 2011), suggests the limitation of individuals in participating in sports and in the context of activities of daily living (ADLs). The possibility of stabilizing and controlling the movement of the foot is due to the use of elastic bandages.

The study aimed to investigate the ability of the 5 cm wide Dynamic Tape (DT) bandage to control the movement and dynamic stability of individuals with excessive pronation.

Characterized as a randomized double blind clinical trial, the study obtained a significance of 5% and statistical power of 80%. The volunteers, being 22 healthy individuals of both sexes with a medium age of 22.0 ± 2.4 years, participated in the study after filling the Free and Informed Consent Form (ICF).

The bandage uses arch support technology to shorten the foot, raise the arch and avoid the calcaneus valgus (BRADY, E 2015) .To analyze the effect of using bandages, three tests were performed: navicular drop test (with subtalar in neutral and weight-bearing), Y test and palpation test of the iliac crests (from the anterior superior iliac spine to the medial malleolus). The reassessment was carried out after applying the bandages.

After applying the DT, the same procedures were performed. The intra-examiner reliability of this measure was analyzed in a pilot study, with n = 10 feet. The ICC of the navicular fall in this study was 0.78-0.95.

The project was evaluated by CEP-FCM-MG (CAAE: 98712818.5.0000.5134). Participants were randomly divided into an experimental group and a control group, with 13 and 9 participants in each group, respectively. To compare the results of the Y Test and the fall of the navicular before and after the application of the bandage, we used the Wilcoxon test and to compare the experimental and control groups, we used the Mann-Whitney test.

Twenty-two people were evaluated, 13 people from the experimental group (traditional) and 9 people from the control group (neutral). After applying the bandages, the measurement of limb length did not change. Alignment was maintained before and after applying bandages to both groups. The results of the Y test showed no difference before and after the application of the bandages. Due to the decline of the navicular, the values measured after the bandaging of the two groups were significantly reduced.

The results of the present study showed that the bandage altered the result of the navicular drop test, showing an effect on pronation control.

Descriptors: pronation; movement; tape

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Validation of a biomechanical model of the human ankle joint for personalised orthopaedic treatments via a dynamic simulation approach

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Introduction: Total Ankle Replacement is becoming an increasingly common surgical procedure for patients suffering from ankle arthritis. However, it still suffers from unsatisfactory clinical results. To improve both clinical outcomes and surgical techniques, an image-based, in-silico model of the human ankle joint complex that includes the three-dimensional bone geometries, cartilage compensation, and ligament fibre recruitment was developed [1] and validated against experimental data [2,3]. In the present study, the mechanical response of the model was analysed with natural and artificial articular surfaces representing common articular surfaces of Total Ankle Replacement. The response of the model was compared to experimental data using the corresponding loading curves from the experiments.

Methods: 3D models of the ankle bones were obtained from CT scans of an anatomical specimen. Artificial articulating surfaces (one cylindrical, and two cones with lateral or medial apexes) were designed to mimic the natural shapes. The model was created in ADAMS (MSC Software Corporation, California, USA) and included a number of ligaments from an anatomical atlas modelled according to a previous study [1,4]. The present personalisation of the model was achieved by importing the exact internal-external rotation and inversion-eversion loads from corresponding experimental measurements [3]. Model predictions, in terms of angular displacement of the tibiotalar, subtalar and ankle complex joints, were compared to the experimental kinematics [3].

Results: The load-displacement patterns compared well for each surface and joint (Figure 1). For the ankle joint complex, the mean range of angular displacement differed by 8.5 deg from that with the natural surfaces, and by 1.0 deg with the three artificial surfaces. The better model prediction with the artificial surfaces may be accounted for by the elementary geometries and the more rigid interfaces compared with the natural joints. In other words, the behaviour of the cartilage was not modelled. By applying the same load to the artificial surfaces, the predicted angular displacement was very similar, with differences in the physiological displacement smaller than 3 deg.

Conclusion: This study aimed at employing a validated personalised three-dimensional model of the ankle joint for the in-silico assessment of the mechanical behaviour of common articular surfaces used to replace the tibio-talar joint. The present validation via comparison with experimental data suggests that this model may be used in the future to evaluate the design of prosthetic devices for total ankle replacement with different articular surface geometries.

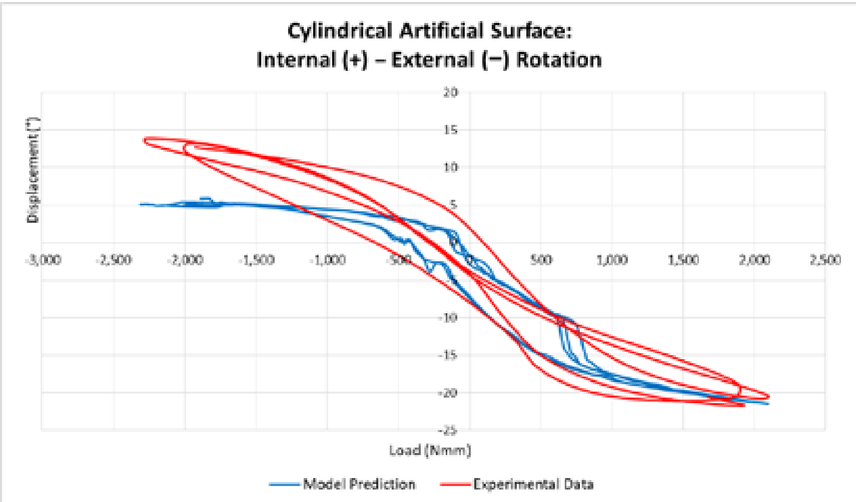

Figure 1. A typical load-displacement graph superimposing model prediction (blue) and experimental data (red). Here the cylindrical surface under torque in internal-external rotation. The patterns compare very well, apart from the range of angular displacement in internal rotation.

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What is the influence of severity levels of knee osteoarthritis on gait initiation?

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BACKGROUND: Gait initiation (GI), requires anticipatory postural adjustments (APAs) to prevent episodes of disorders during in gait [1]. The APAs have been investigated in individuals with Parkinson disease [2], severe Knee osteoarthritis (KOA) [3], older adults [4] and obese populations [5]. However, to date, there are no investigations on postural adjustments in older adults with different severity levels of KOA. The KOA is a chronic and progressive condition, and the severity level could strongly affect GI [6]. Therefore, the present study aimed to evaluate the APAs adopted by older adults with KOA at different severity levels during GI. The results of this study could contribute to establishing more effective rehabilitation strategies for this population.

METHODS: Sixty-seven older adults with knee osteoarthritis and 11 healthy older adults control were evaluated bilaterally (women = 54; men = 24). Eligibility criteria included all individuals who were diagnosed with KOA at the levels mild, moderate, and severe, according to the American College of Rheumatology criteria [7]. The volunteers could not present other musculoskeletal, neuromuscular or vestibular alterations, and could not use mobility aids during the assessment. All volunteers signed the informed consent form approved by the Ethics Committee. The center of pressure trajectory during gait initiation was evaluated with a force platform, and was divided into four phases: three anticipatory postural adjustments, and a locomotor phase (Figure 1). The length, duration, and velocity of each phase were calculated [5].

FINDINGS: The results showed that during the right and left limbs swing forward, the severe and moderate knee osteoarthritis groups presented a significant reduction ($P < 0.003$) in the length of anticipatory postural adjustment phases, locomotion, duration, and velocity (Figure 2). The severe knee osteoarthritis group presented a significantly higher body mass index ($P < 0.003$) than the other groups. However, just the healthy group presented a correlation between body mass index and anticipatory postural adjustments.

INTERPRETATION: Our results demonstrated that older adults with severe and moderate levels of knee osteoarthritis adopt longer lasting and slower anticipatory postural adjustment phases, lower locomotion, and lower center of pressure displacement during gait initiation, suggesting that this population has adaptive strategy in performing gait initiation, which is significantly changed by the knee osteoarthritis severity level.

KEYWORDS: Anticipatory postural adjustments, Gait initiation, Knee osteoarthritis, Severity

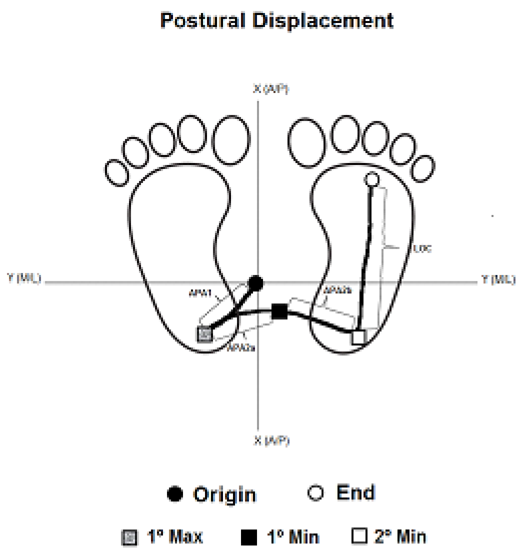

Figure 1. Divisions of the center of pressure (CoP) displacement phases during the four phases of gait initiation.

The example shows the left leg swinging forward, and the right leg in supporting. The circles represent the origin and end of the GI, and the squares represent the first maximum and first and second minimum.

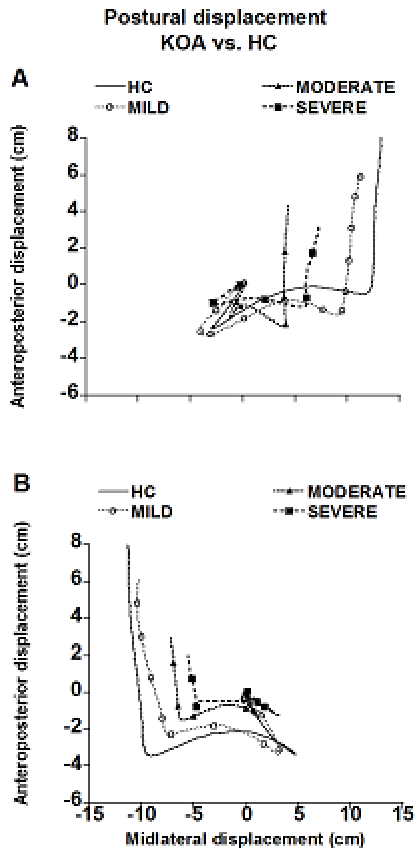

Figure 2. The center of pressure (CoP) displacement between the groups.

This figure depicts the center of pressure (CoP) displacement between the groups with KOA (mild, moderate, and severe) and the control group for left (A) and right (B) limb swinging forward, performed by one subject each group. The initial position (origin) was aligned to show the difference between groups.

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What's happening in my Achilles tendon? The effects of running in different footwear

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In 2012 the ultrasound based method called speckle tracking was first used to describe non-homogenous deformation within the human Achilles tendon and since then a number of research groups internationally have consistently confirmed the results. There is a consensus that during dorsiflexion and plantarflexion motion the deeper portions of the tendon move more than the superficial portions. This has been shown in a variety of activities and different activation modalities of the triceps surae. Recent research now indicates that this non-uniform deformation may be a biomechanically beneficial behaviour indicative of a healthy tendon and that a reduction in non-homogeneity may be negative for tendon function and possibly an etiological mechanism for chronic tendon injury. Running barefoot or in minimalistic shoes has been associated with Achilles tendon injuries and this raises the question whether these conditions affect the internal dynamics of the tendon in a negative manner, i.e. by reducing non-homogenous behaviour. New data now support this hypothesis showing that the differences in displacement between deep and superficial portions of the tendon are decreased when running barefoot or in minimalistic shoes as compared to traditional running shoes. This could be expected to be a mechanism that places the Achilles tendon at risk for injury.

My presentation at iFAB 2020 will take us on the scientific journey from initial indications of non-homogeneity in the human Achilles tendon to the most recent studies exploring the effects that different footwear have on this during running. I will discuss the present state of knowledge concerning possible consequences of non-homogenous tendon deformation during running.

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