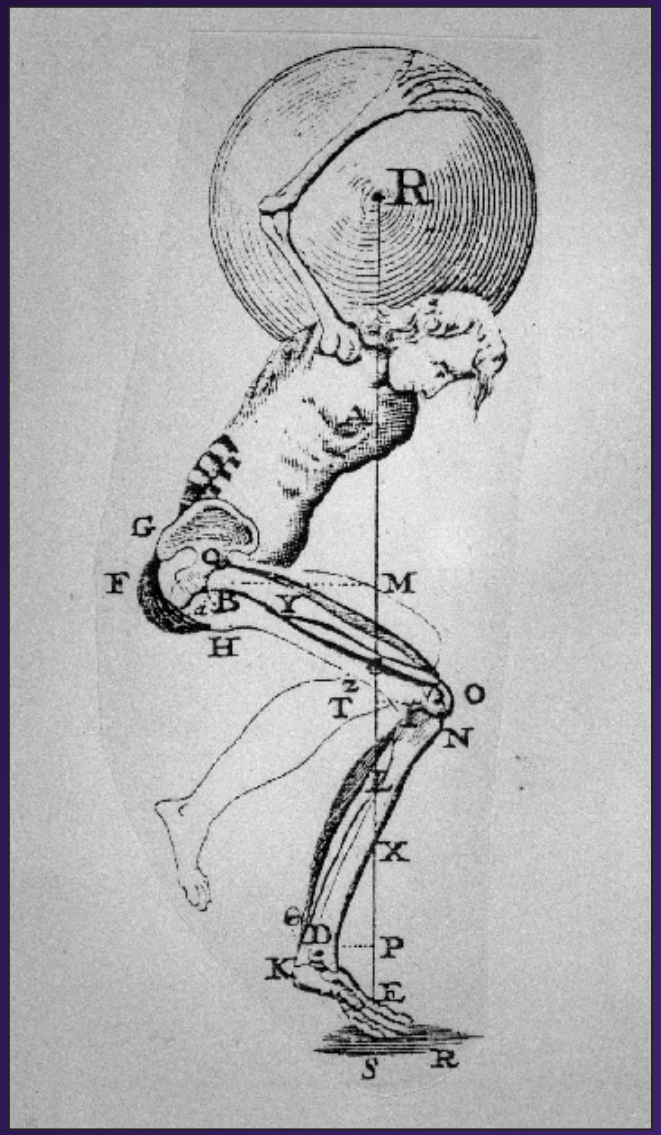

Musculoskeletal Biomechanics

BIOEN 520 | ME 527

Mini-Lab 5

Journal Club

The first rule of Journal Club is:

- You do not talk about Journal Club.

What is a journal club?

- Paper review
- Topic of interest
- Conference preparation
- Lab meeting

Why do journal club?

- Learn about field of interest
- Learn about a new field
- Keep abreast of new developments
- Foster informal discussion and interaction
- Develop presentation skills
- Develop critical thinking skills
- Promote social interaction

Format of journal club

- 1x or 2x a month
- Small group
- Rotating discussion leader
- Circulate paper, participants read in advance
- Discussion leader can seed questions
- Discussion leader presents an overview
- Group dissects/critques paper

Tips for good journal club

- Interesting topics/good papers
- Everyone comes prepared!
- Keep it moving/humor/add content
- Ask questions of the group

Tips for good journal club

- Use a rubric
  - Does paper address a relevant question
  - Were the methods appropriate to answer the question?
  - What were the results/findings?
  - Are the results valid?
- Or straight chalk
  - Intro, methods, results, discussion
- Or mix and match
  - Cover a wide range of topics

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Accuracy and feasibility of high-speed dual fluoroscopy and model-based tracking to measure in vivo ankle arthrokinematics

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Questions to consider when reading

- Q1: How was cadaver ROM/gait testing conducted? How was force repeatably applied? Does that matter?
- Q2: Consider how the anatomical coordinate systems were generated – is this method superior to template matching? Would static misalignments be ignored with this method?

Questions to consider when reading

- Q3: How were beads included in model-based tracking data? Via technical coordinate systems?
- Q4: How were the data from the two trials synced (heel strike to foot flat, and foot flat to toe off)?

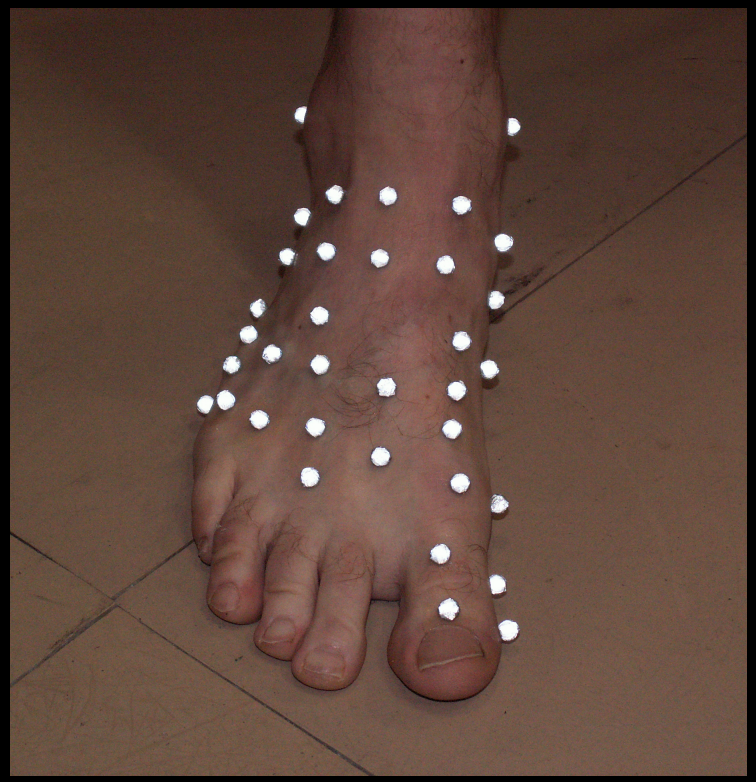
Introduction

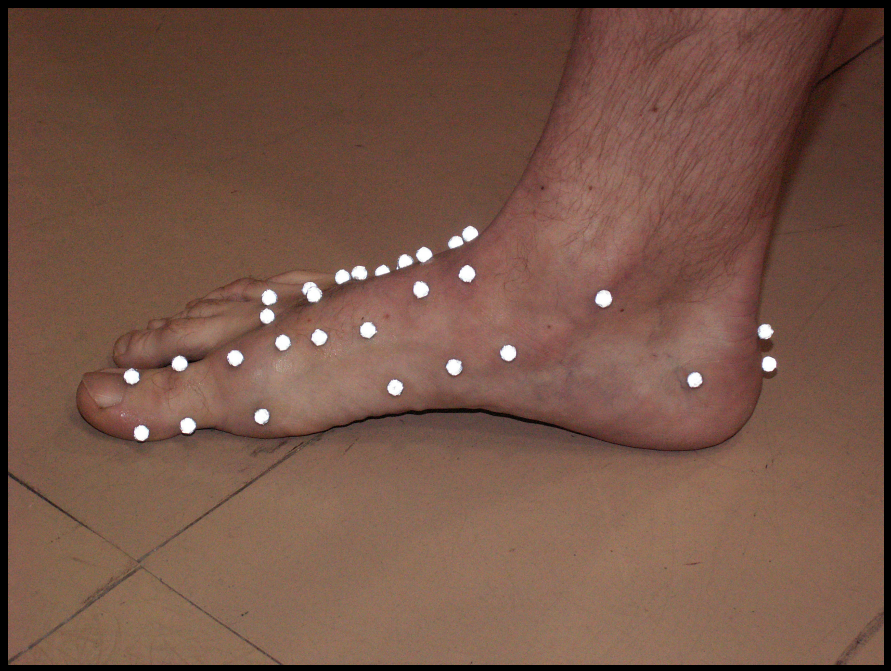
- Ankle joint complex
  - Tibiotalar, tibiofibular and talocalcaneal (subtalar)
- Restriction of motion of one could lead to issues with the other
- Subtalar OA after ankle fusion (Coester 2001)
- Desirable to have accurate kinematics

Introduction

- Retro-reflective markers
  - Lack of space, talus is deep, skin motion artifact
- Intra-cortical bone pins
  - Very accurate, but invasive (Westblad 2002, Arndt 2004)
- Single plane fluoro
  - Out of plane motion (Scott Banks at UF)
- Biplane fluoro
  - Quasi-static (MGH – Li et al., Duke – DeFrate et al.)
  - Lack validation (Steadman Hawkins, Henry Ford)

Retro-reflective markers





Numerous authors and groups

Strengths: dynamic; link foot to rest of the body; capture hindfoot motion

Weaknesses: number of markers; rigid body assumption; skin motion artifact

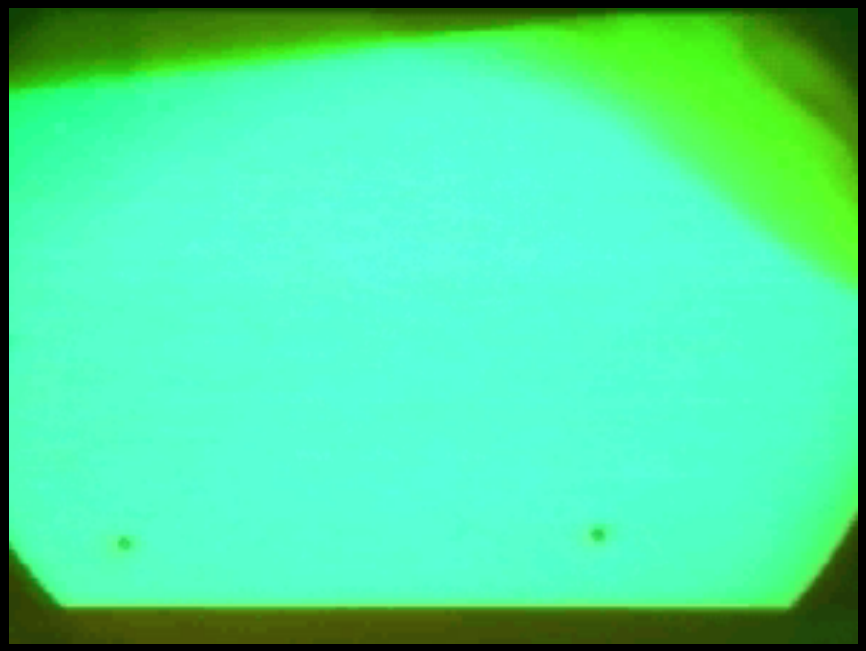
Bone pins

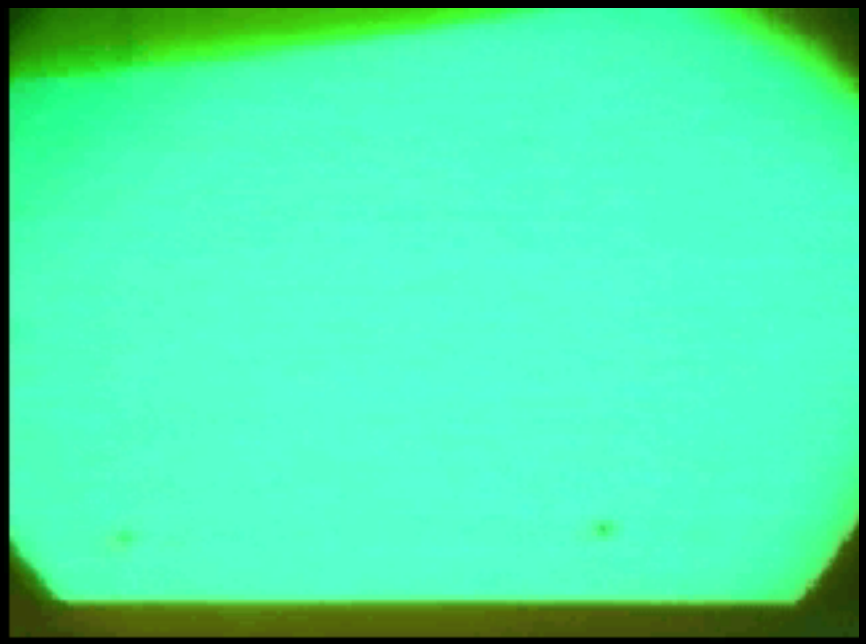
Arndt A, et al., Journal of Biomechanics, 40, 2007

Strengths: dynamic; multiple bones; gold standard

Weaknesses: invasive; not be used in routine clinical care

Fluoroscopy systems





De Clercq D, et al., Journal of Biomechanics, 27, 1994

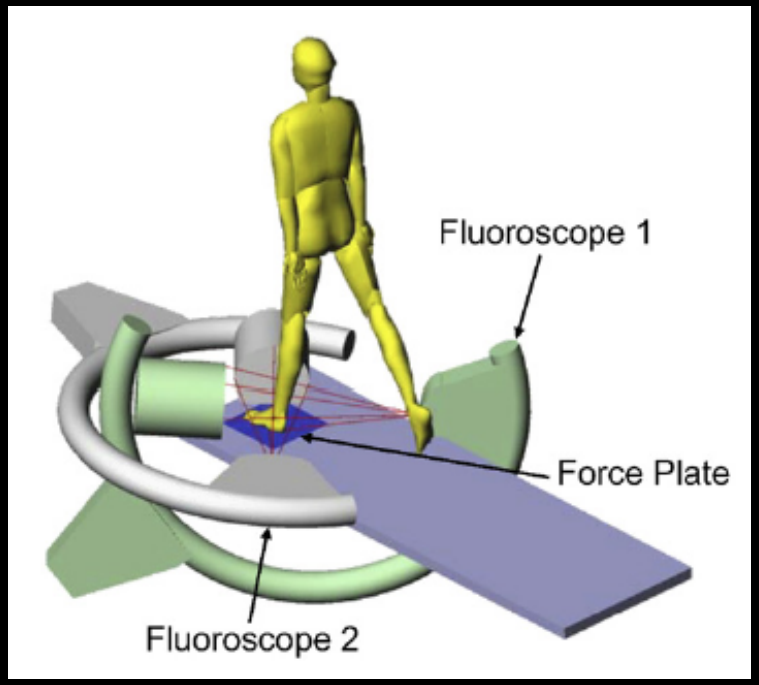
Strengths: dynamic; multiple bones

Weaknesses: single plane; exposure to radiation

Fluoroscopy systems

Yamaguchi S, et al., Foot and Ankle International, 30, 2009
Strengths: dynamic; multiple bones; 3D-2D model registration
Weaknesses: slower frequency; hindfoot only; exposure to radiation; 3D-2D

Fluoroscopy systems



Li G, et al., Journal of Biomechanics, 41, 2008
Caputo A, et al., American Journal of Sports Medicine, 37, 2009
Strengths: dynamic; multiple bones
Weaknesses: portion of stance; no oblique images; exposure to radiation

Introduction

- Independent validation recommended for each biplane system, joint, and activity. (Tashman 2008)
- This group developed a high speed biplane fluoroscopy system with an instrumented treadmill.
- Therefore…

Objective

- Primary: Quantify the accuracy of high speed biplane fluoroscopy system and model-based algorithm for tracking arthrokinematics of the ankle and subtalar joint.
- Demonstrate feasibility of protocol for measuring arthrokinematics for a normal volunteer during treadmill gait.

Methods

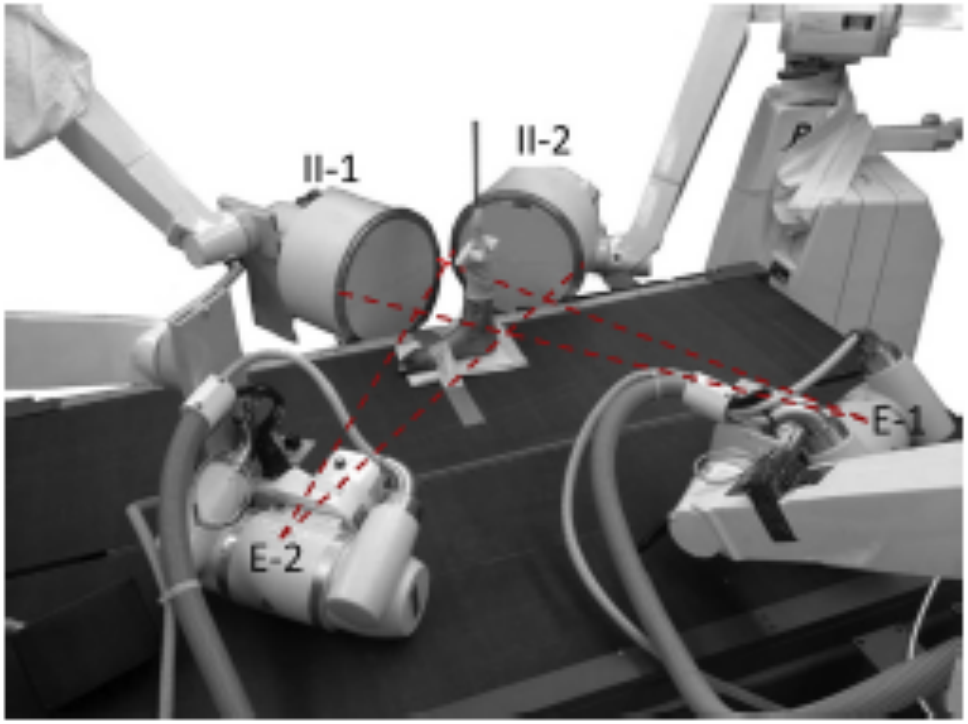


Fig. 1. Custom dual fluoroscopy system positioned around a dual-belt instrumented treadmill to image in vivo articulation of the subtalar and tibiotalar joints. The specimen was placed in the combined field of view of both fluoroscopes. Dashed lines represent projected X-ray beam. E = emitter, II = image intensifier.

Methods

- 2 fresh-frozen cadaveric feet
  - 52-year-old M; 81-year-old F
  - Screened for OA
  - Four 2-mm steel balls – tibia, talus and calcaneus
  - 10-mm diameter rod in tibia shaft

Methods

- Custom biplane system
  - X-ray emitters, 12” image intensifiers, high-speed cameras and a dual instrument treadmill (Kapron 2014)
- ROM trials
  - 100 Hz
  - Dorsiflexion/plantar flexion, inversion/eversion, and internal/external rotation by manipulating tibial rod
  - Toes taped to treadmill
- Q1: How was cadaver ROM testing conducted? How was force repeatably applied? Does that matter?

Methods

- Gait trials moderated by raising and lowering tibia rod
- 300 hz 0.5m/s and 1.0 m/s
- Heelstrike to midstance; midstance to toe-off
- Gait and ROM trials:
  - 67-75 kV, 1.3-2.0 mA
  - 608x600 resolution, 1 ms exposure
- Q1: How was cadaver gait testing conducted? How was force repeatably applied? Does that matter?

Methods

- CT (0.75mm slice thickness, 256 mm FOV, 512x512, 130 kV, 140 mAs)
- Bone segmentation with Amira
- Bead tracking:
  - Beads segmented and fit to sphere
  - Bias = 0.017mm, precision = 0.113mm (Kapron 2014)
- Model-based tracking:
  - DRR/fluoro optimization (Bey 2006)
  - Beads masked from CT

Methods

- Anatomical coordinate systems
  - Methods defined in detail in section 2.7
- Q2: Consider how the anatomical coordinate systems were generated – is this method superior to template matching? Would static misalignments be ignored with this method?

Methods

- Bead position
  - Model-based tracking vs. bead-based tracking
  - Bias = mean difference in inter-bead distance
  - Precision = standard deviation of difference
- Q3: How were beads included in model-based tracking data? Via technical coordinate systems?
- Joint angles and translations (section 2.8.2)
- Bone-to-bone distances (section 2.8.3)
  - Calculated for both bead-based and model-based

Methods

- Feasibility application to a live subject
  - 28-year-old F
  - 0.5 m/s and 1.0 m/s
  - 62-66 kV, 1.4-1.8 mA
  - 608x600 camera resolution
  - 300 Hz and 1.5 ms exposure
  - Total fluoro time was 31 s
  - CT scan (1.0 slice thickness, 322 mm FOV, 512x512, 100 kV, 73 mAs

Results

- Model-based bias across all trials & specimens (Table S1):
  - Tibia = 0.31 ± 0.09 mm
  - Talus = 0.41 ± 0.17 mm
  - Calcaneus = 0.50 ± 0.23 mm
- Model-based precision across all trials & specimens (Table S1):
  - Tibia = 0.15 ± 0.07 mm
  - Talus = 0.19 ± 0.07 mm
  - Calcaneus = 0.20 ± 0.10 mm

Results

- Angular model-based bias across all trials & specimens less than 1.68 degrees (Table S2)
- Translational model-based bias across all trials & specimens less than 0.47 mm (Table S3)
- Mean rotational and translation bias across all specimens and trials: 0.25 ± 0.81 degrees and 0.03 ± 0.35 mm
- Mean rotational and translation precision across all specimens and trials: 0.63 ± 0.28 degrees and 0.3 ± 0.12 mm

Results

- In general, joint angles and translations matched well between model-based and marker-based

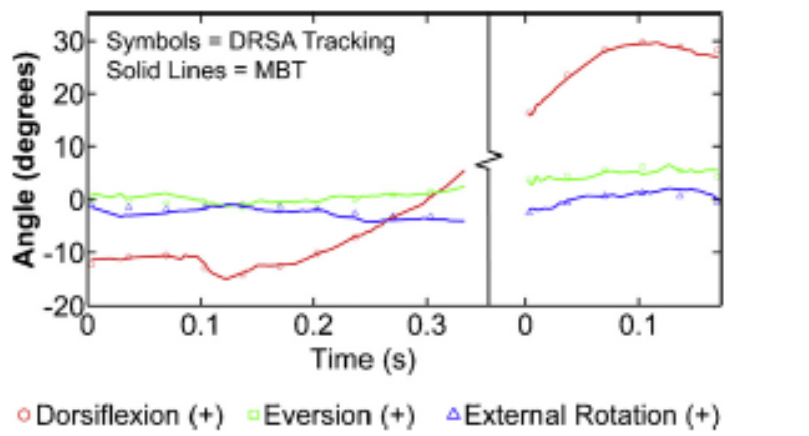
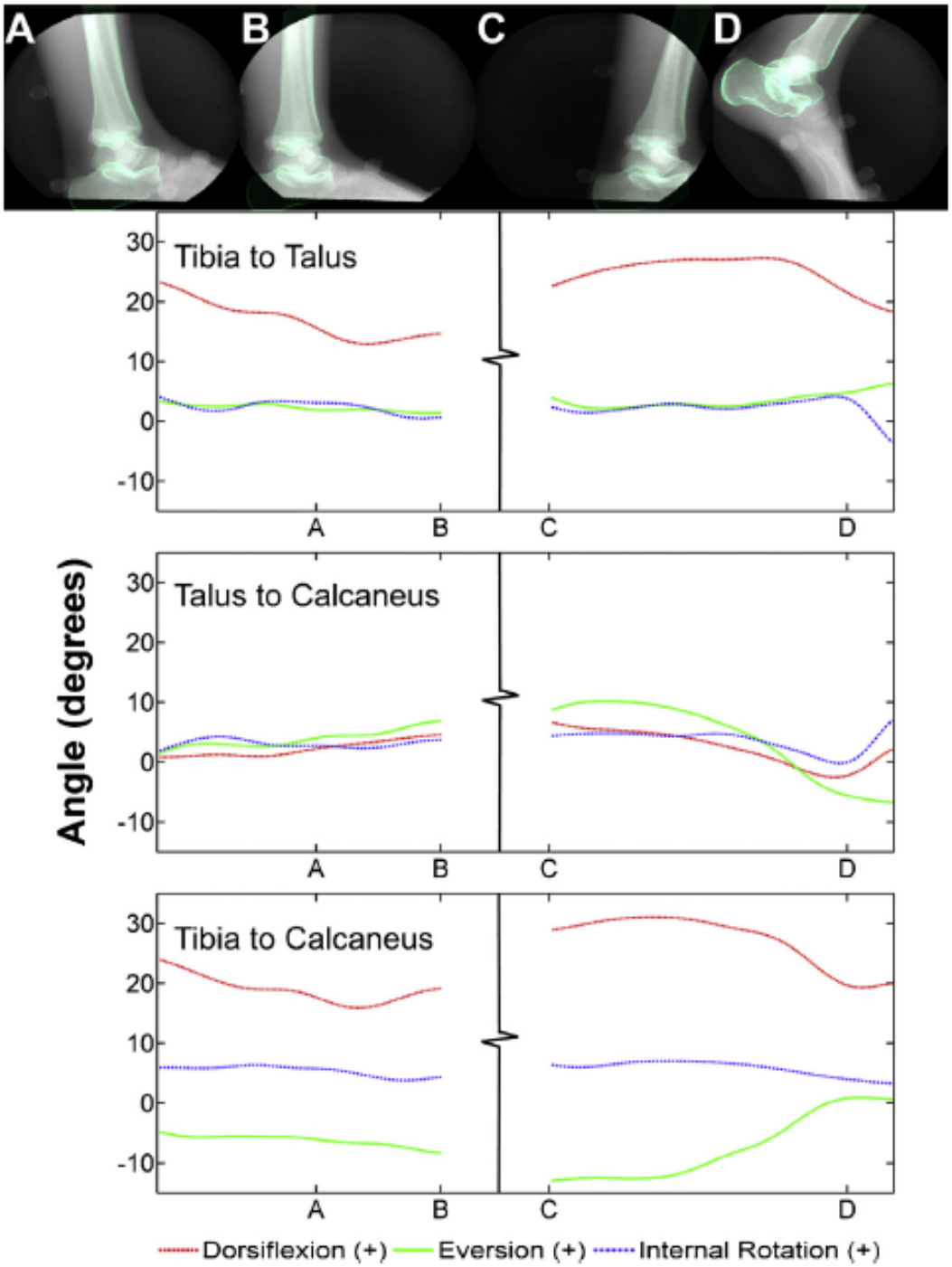


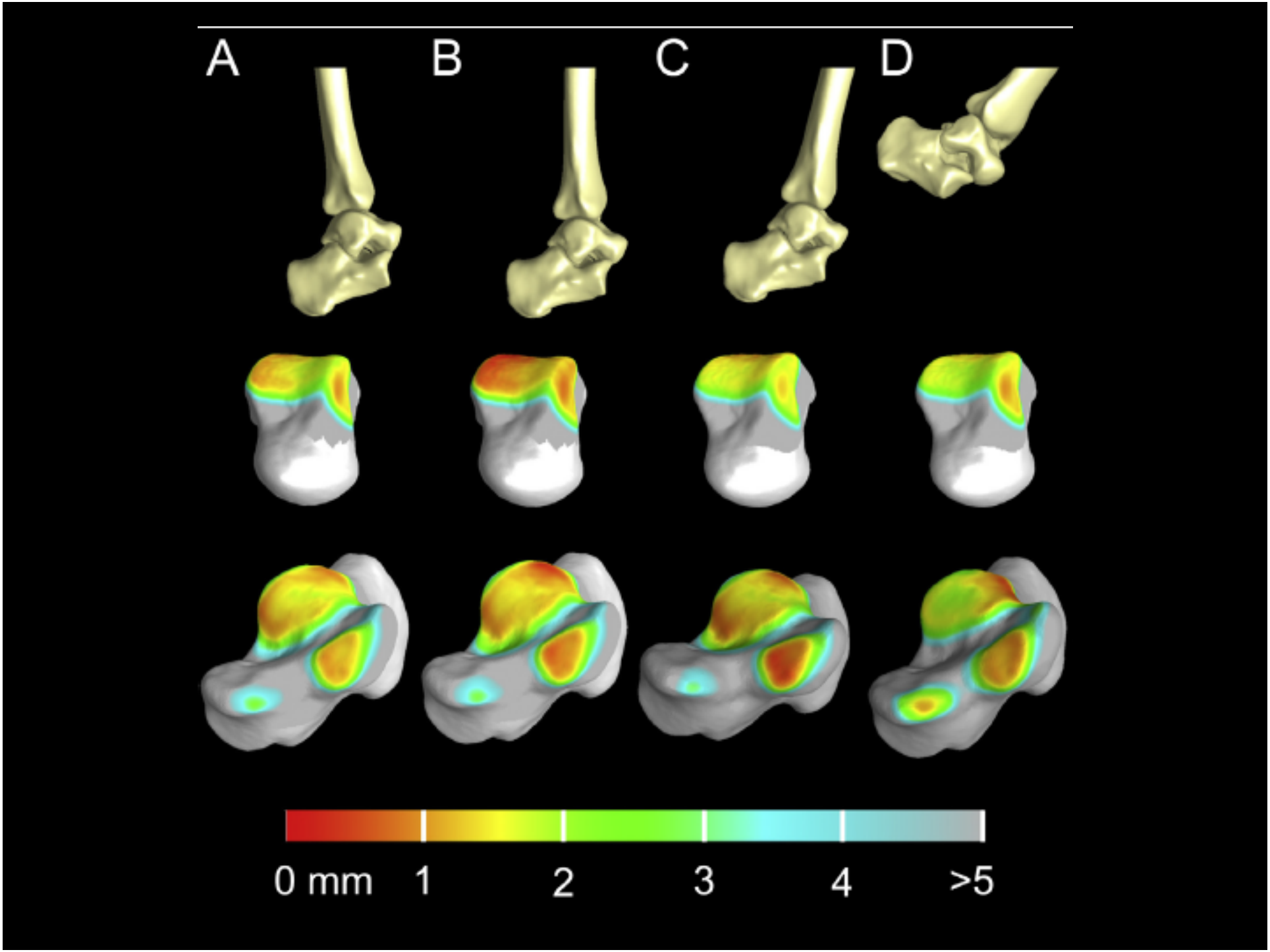
Fig. 2. Plots of the joint angles from the heel-strike and toe-off trials of the first specimen were combined to recreate the gait cycle. The single markers represent joint angle values determined through digital radiostereometric analysis and are plotted every 10 frames. The solid, lines demonstrate the results obtained through model-based tracking, plotted for every frame.

- Q4: How were the data from the two trials synced (heel strike to foot flat, and foot flat to toe off)?


A
B
C
D
Tibia to Talus
Talus to Calcaneus
Tibia to Calcaneus
Angle (degrees)
30
20
10
0
-10
A
B
C
D
Dorsiflexion (+)
Eversion (+)
Internal Rotation (+)

Results

- Bone-to-bone distance measurements for tibiotalar and subtalar were 0.39 ± 0.22 mm and 0.55 ± 0.18 mm (Table S4)


A
B
C
D
0 mm
1
2
3
4
>5

Discussion

- Subtalar and tibiotalar kinematics with errors less than 1 mm and 1 degree
  - Compared to literature
- Successfully tested method on a human subject

Discussion

- Limitations:
  - Cadavers manipulated – not natural gait
    - Therefore larger ranges of motion
  - Treadmill prevents entire gait cycle
    - Better than quasi-static testing
  - Radiation dosage
    - 0.12 mSv

Conclusion

- Bone-based and bead-based can accurately quantify tibiotalar and subtalar kinematics during dynamic motion
- Allow for exploration of subtle ankle pathomechanics
- May serve to validate, standardize, or calibrate gait models.