

# Experimental investigation of the *lower leg trajectory error metric*: implication for the design of ankle-foot prostheses



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## Motivation : need for a prosthetic foot design metric

- Access to affordable, high performance prostheses remains limited [1].
  - No firm consensus on how to design and evaluate prosthetic feet leading to protracted iterative design processes and expensive prostheses [2].
  - The LLTE is a novel, person specific, mechanical based walking performance estimator that can be used to design prostheses to closely replicate reference walking patterns [3].
- AIM:** Understand the correlation and sensitivity between amputees' walking pattern and LLTE values of worn prosthetic foot.

## Method : testing prostheses with varying LLTE values

### Lower Leg Trajectory Error (LLTE)

- Relates the stiffness and geometry of a prosthetic foot to its biomechanical performance [3].
- Quantifies how well a prosthetic foot can replicate a given motion subjected to a reference set of loads.
- A prosthetic foot with low LLTE value means better replication of target walking pattern.

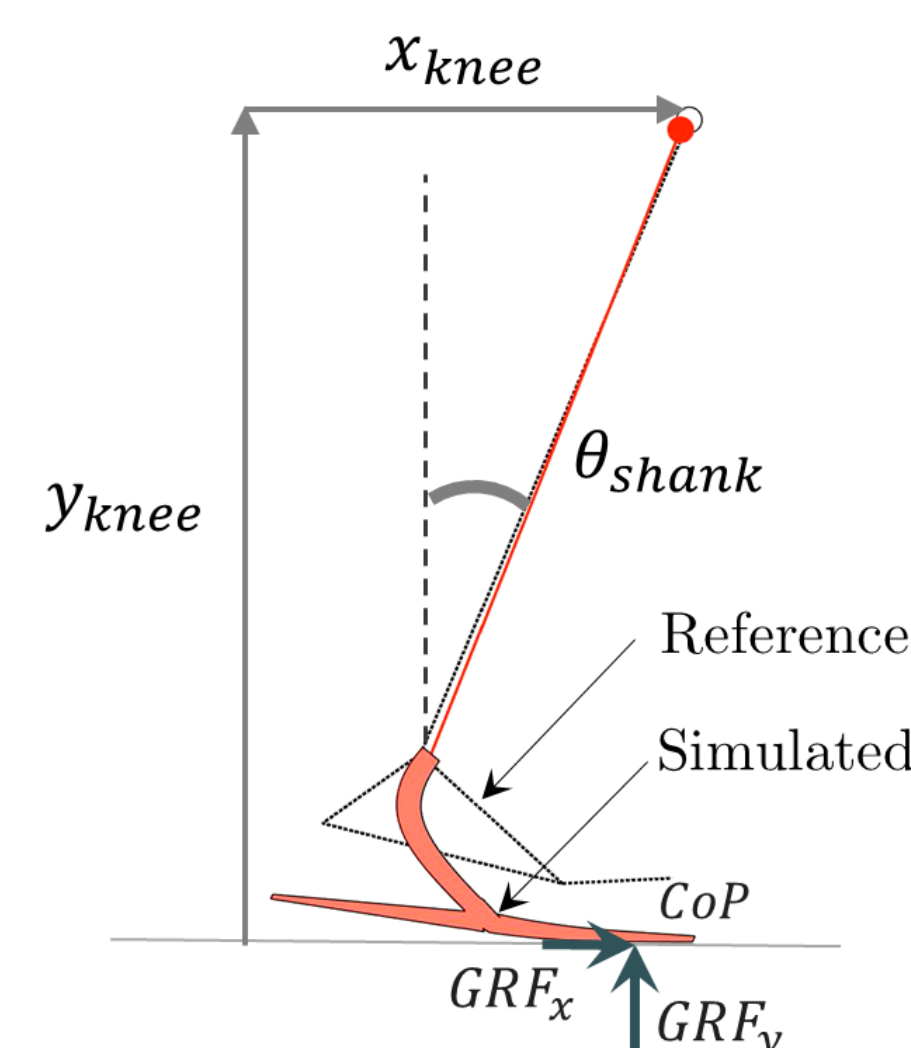


Fig 1: Representative lower leg calculation to evaluate the LLTE

### Experimental Study

- 3 below-knee amputees walked over ground using 5 prototype feet.
- 5 prototypes had varying LLTE values through varying stiffnesses but similar optimized geometry designed for each subject [4] (Fig. 2).
- Prostheses alignment was maintained throughout the walking trials and set by a prosthetist using the predicted optimal case, condition C.

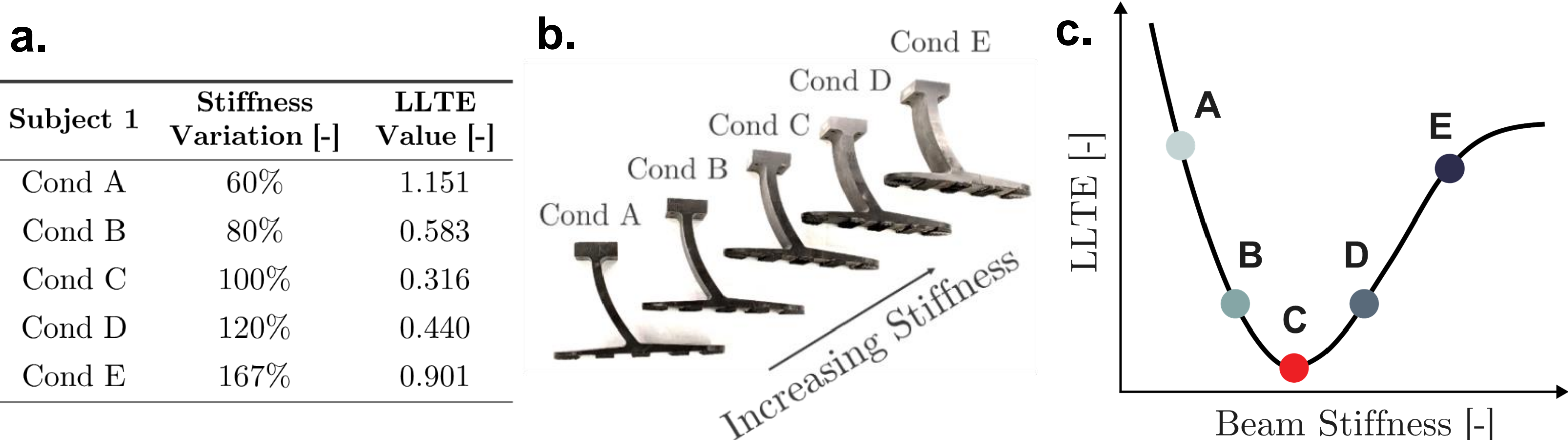


Fig 2: a. Table with prototype stiffnesses and LLTE values, b. Photograph of tested prototypes for one subject, c. LLTE values of the prosthetic feet tested by each participant, with optimal foot, condition C

## Results : prostheses LLTE values seems correlated to walking performance

- Variations in LLTE value and foot stiffness led to variation in measured ground reaction forces, center of pressure, and lower leg kinematics (Fig. 3). Feet with lowest LLTE value best replicated target walking pattern.

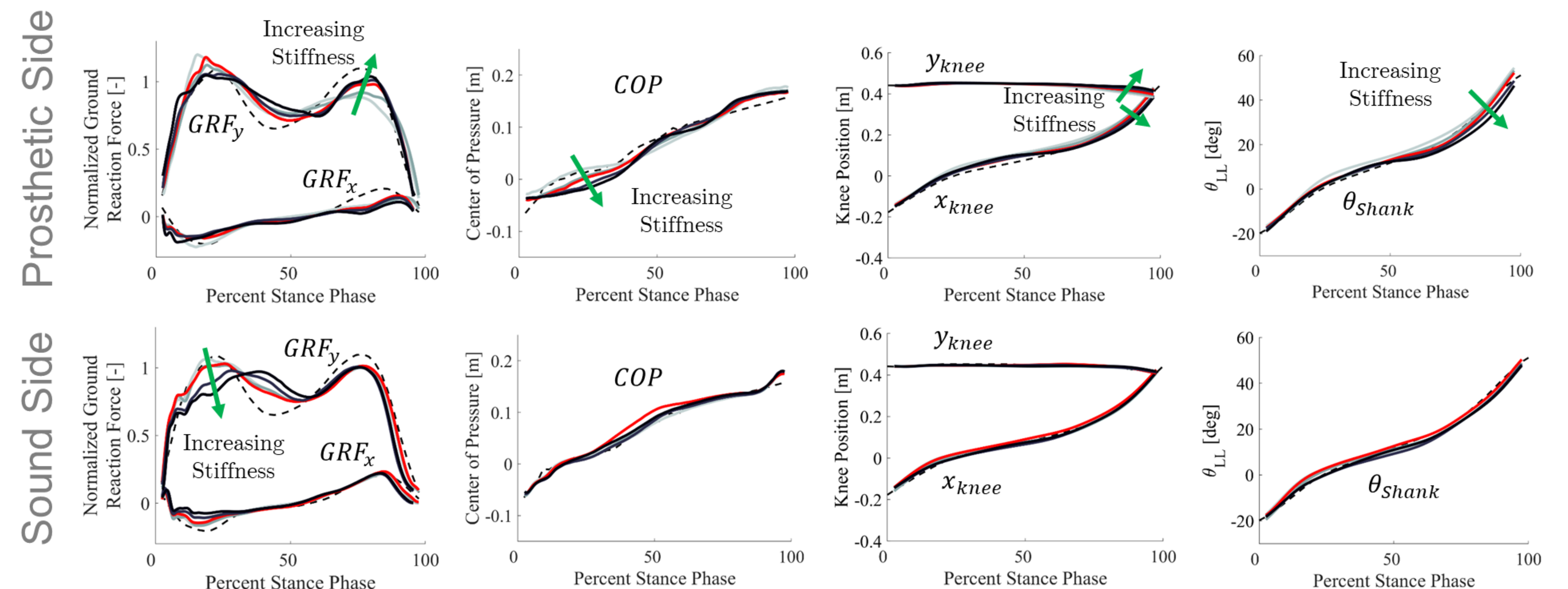


Fig 3: Sampled subject measured stance phase gait parameters. --- Physiological Data — CondA — CondB — CondC — CondD — CondE

- Subject's preference (PEQ-MS-type questionnaire, Fig. 5) and deviation from target able-bodied walking pattern (Fig 4.) aligns with the LLTE values.
- Near the LLTE optimal value, subject showed reduced sensitivity to LLTE variations.
- Amputees seem to prioritize kinematics over kinetics: kinematic deviations were 2.4 times lower on average than kinetic deviations.

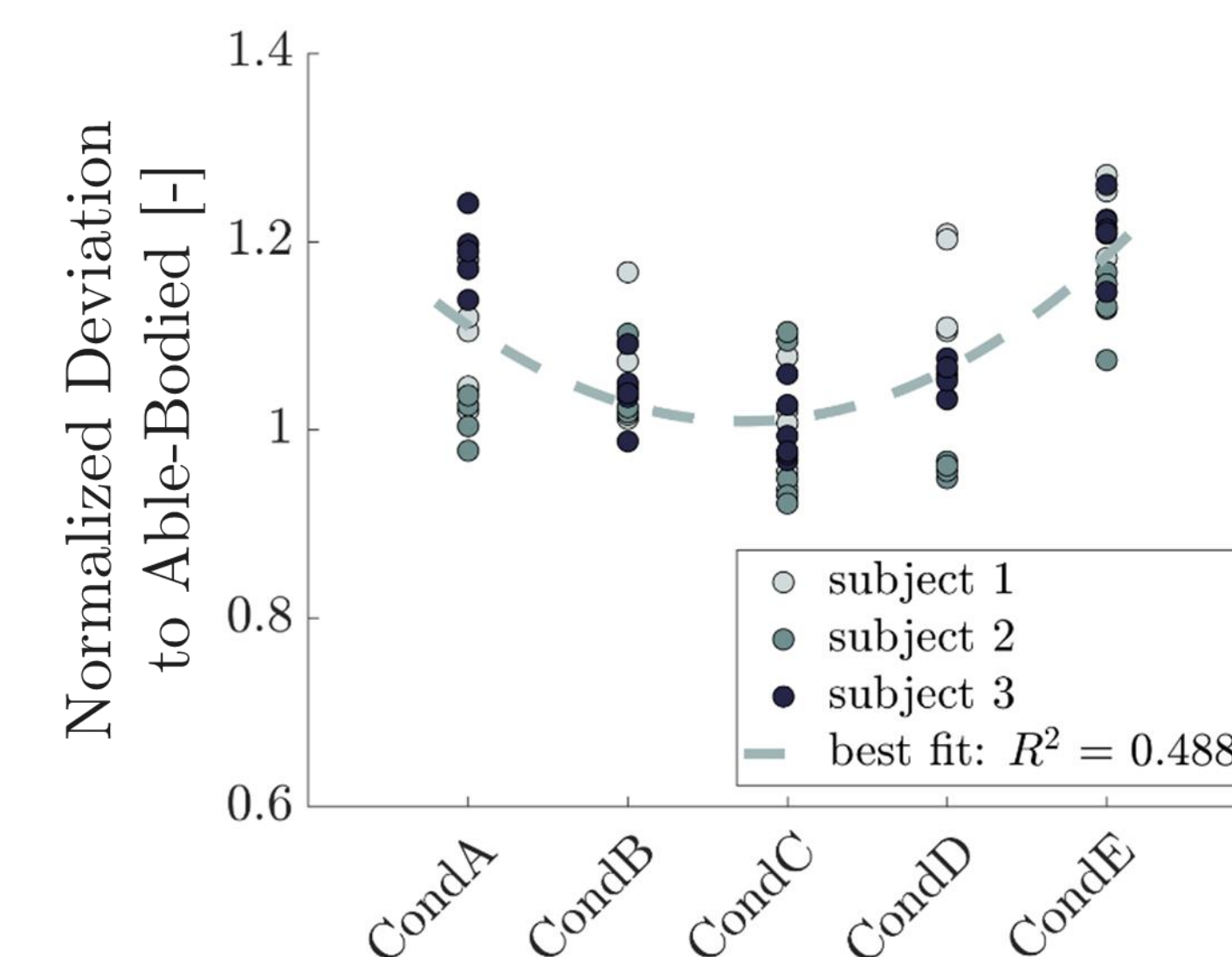


Fig 4: Normalized Deviation to able-bodied walking pattern

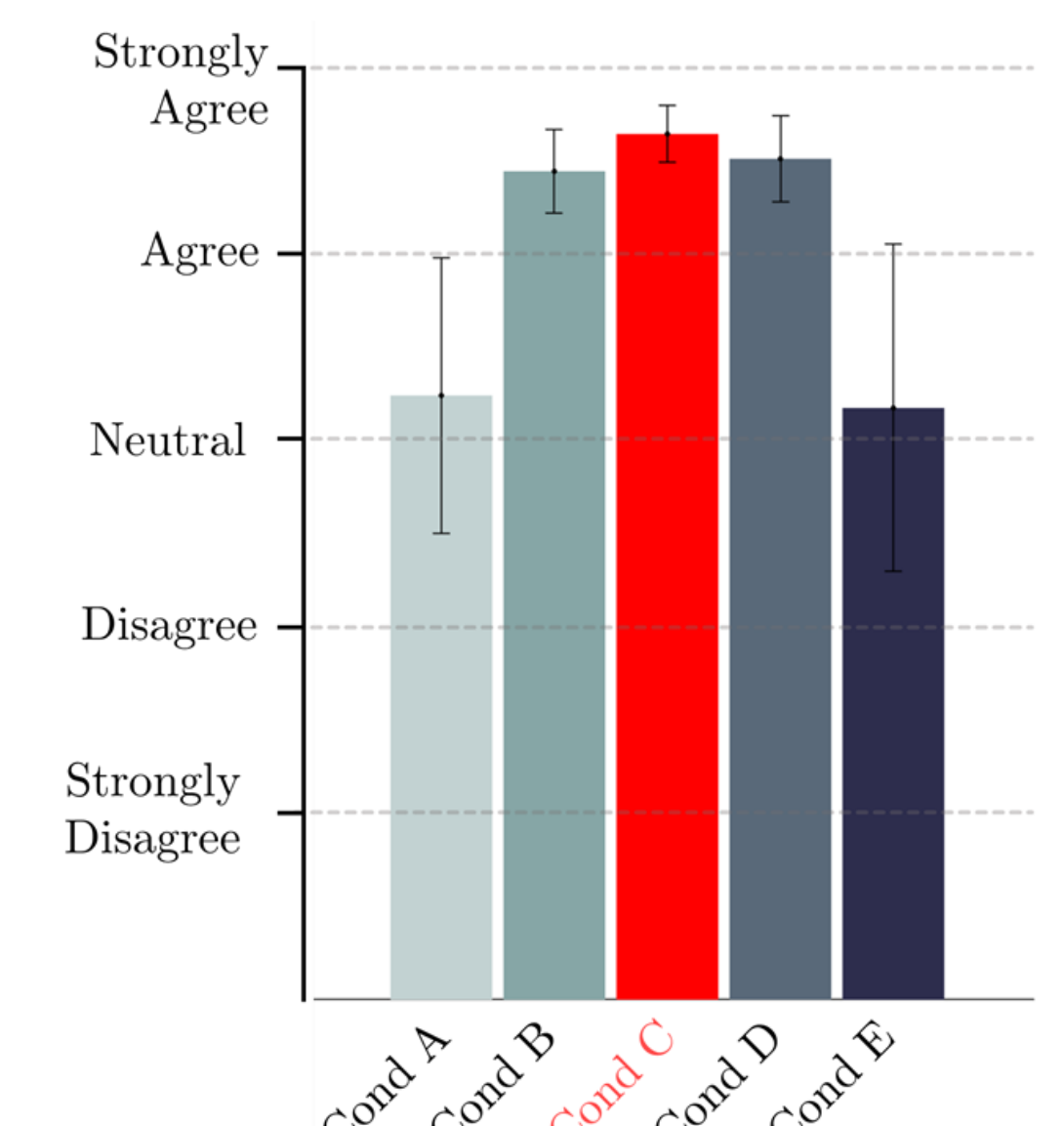


Fig 5: Average questionnaire results across all participants.

## Conclusion : LLTE a metric for design and evaluation of prosthetic feet

- Prosthetic feet with lower LLTE value enable users to more closely replicate a target walking pattern.
- Reduced sensitivity around LLTE optimal enables foot sizing similar to a shoe store approach as well as multi-activity feet designs.
- The LLTE value could provide insight as an amputee independent measure for evaluating existing prostheses.

### Acknowledgment:

The authors would like to thank Mr. DR Mehta and Dr. Pooja Mukul at the Jaipur Foot organization (BMVSS), and Rebecca Stine and Martin Buckner at Northwestern University for their support.

[1] World Health Organization; 2017  
 [2] Hofstad, Cochrane 2004  
 [3] Olesnavage, TNSRE 2018  
 [4] Olesnavage, JMD 2018