Dynamic Prosthetic Interface Cycling Mount for Transfemoral Amputees: A Single Subject Kinematic Study

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INTRODUCTION

- Prosthetic cycling mounting systems provide low impact aerobic exercise
  - recreational and competitive
- Variance between amputees and bicycle designs = custom prostheses
  - Costly to fabricate
- Current designs lack adjustability and limit user mobility, Figure 1
- The Dynamic Prosthetic Interface (DPI) Biking Mount, Figure 2
  - Multiple degrees of freedom, user adjustability, and maintains sufficient stiffness/strength for cycling

Figure 1: Conventional Mount rigidly fixed to the bike frame.

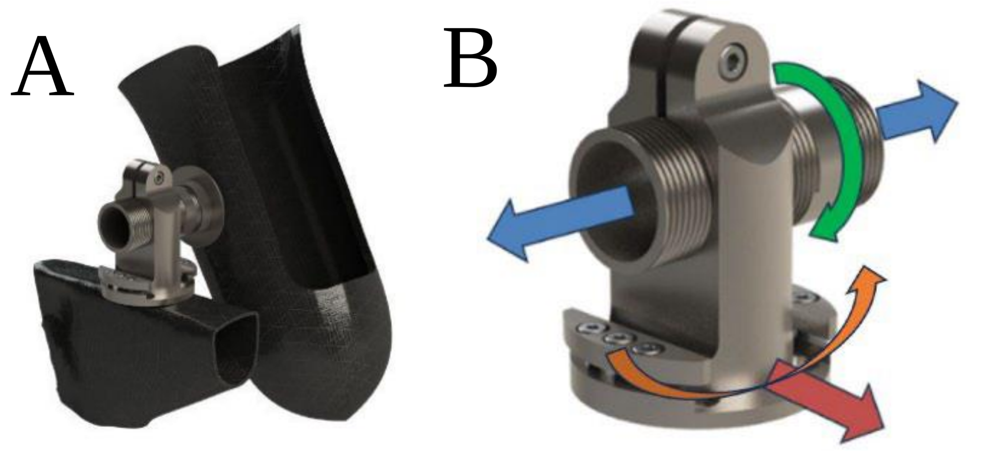

Figure 2: DPI Novel Mount. (A) DPI attached to prosthetic socket and frame mold. (B) DPI multiple degrees of freedom.

PURPOSE

- The purpose of this study is to biomechanically compare a novel prosthetic mounting system against a conventionally used transfemoral prosthetic mounting system. The novel mount seeks to improve adjustability while enhancing biomechanical performance. This study will elevate accessibility to athletic activity and address the literature gap for research involving transfemoral amputees.

METHODS/EXPERIMENT

- Single U.S. paralympic athlete with a transfemoral amputation
- Experimental Conditions:
  - Conventional Mount, Figure 1
  - Novel (DPI) Mount, Figure 2
- Data collection:
  - Qualitative physical effort
  - Tekscan: Pressure map sensors placed within prosthetic socket
    - Assess pressure distribution
  - Surface electromyography: 4 wireless sensors on driving leg, Figure 3
    - Vastus medialis, biceps femoris, medial gastrocnemius, and tibialis anterior
  - Eight Optitrack motion capture cameras and retroreflective markers arranged per STT systems
    - Allowed for 3D reconstruction of the participant, Figure 4, and kinematic assessment

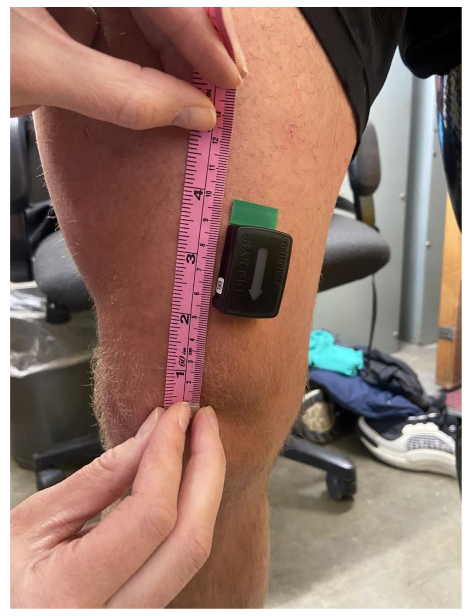

Figure 3 (Left): Surface electromyography, EMG, sensor on the vastus medialis.

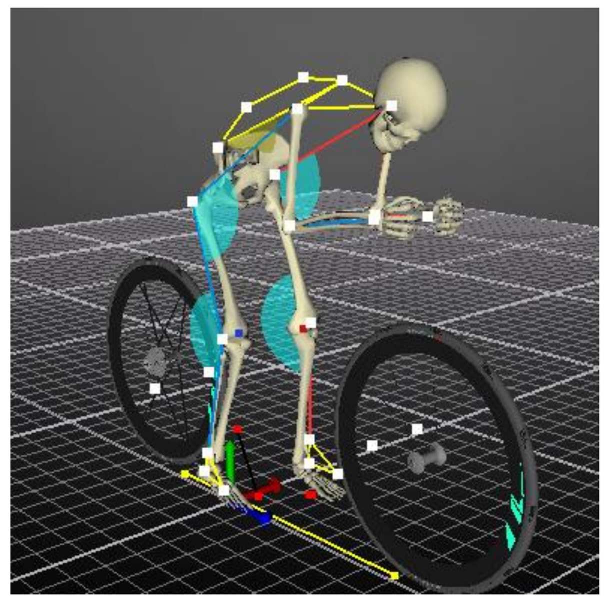

Figure 4 (Right): 3D model of participant using STT Systems and Optitrack Motive.

METHODS

- Each session consisted of a warmup followed by eight cycling trials organized within a single Zwift workout, Figure 5:
  - Trials 1,2, and 3 simulated high intensity riding (triathlon cycling)
  - Trials 6,7 and 8 represented low intensity riding (recreational cycling)
  - Trials 4 and 5 consisted of 30 second maximal effort, simulating race level accelerations-followed by 2.5 minutes of recovery
- Programmed terrain changes influenced riding behavior and posture
- All trials were followed by active recovery
- Measured intensity was performed continuously throughout trials based on power output and rotations per minute

Figure 5, Above: Programed workout using Zwift Software connected to a bike trainer allowing for automatic changes in cycling demands.

Figure 6, Right: Athlete cycling during a trial. Note retroreflective markers, cameras, and live data recording on computer monitors.

RESULTS

- Motion capture trials 3,5,7 were excluded due to incomplete recordings or insufficient marker quality. EMG tibialis anterior was excluded due to inconsistency and poor repeatability.
- Changes in pressure distribution and activation within the novel DPI mount included:
  - 31.5% increase in contact area within prosthetic socket, Figure 7
  - 28.3% increase in quadricep activation
  - 30.4 % decrease in hamstring activation
  - 44.7% decrease in calf activations
- The novel DPI mount produced notable changes in lower body kinematics between conditions:
  - Reduced ankle and hip fore-aft excursion
  - Greater and consistent knee flexion
  - Reduced magnitude in pelvis rotation, Figure 8
  - Signs of open posture shown in hip flexion
  - Altered vertical hip motion patterns
- Participant noted improvements in perceived effort, comfort and weight distribution.

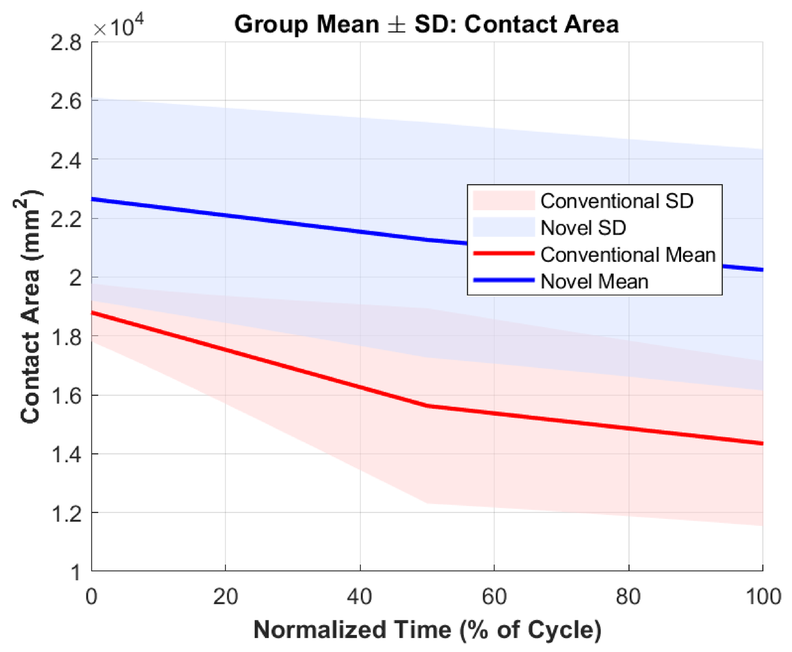

Figure 7: Group mean waveforms with standard deviation bands for contact area.

RESULTS

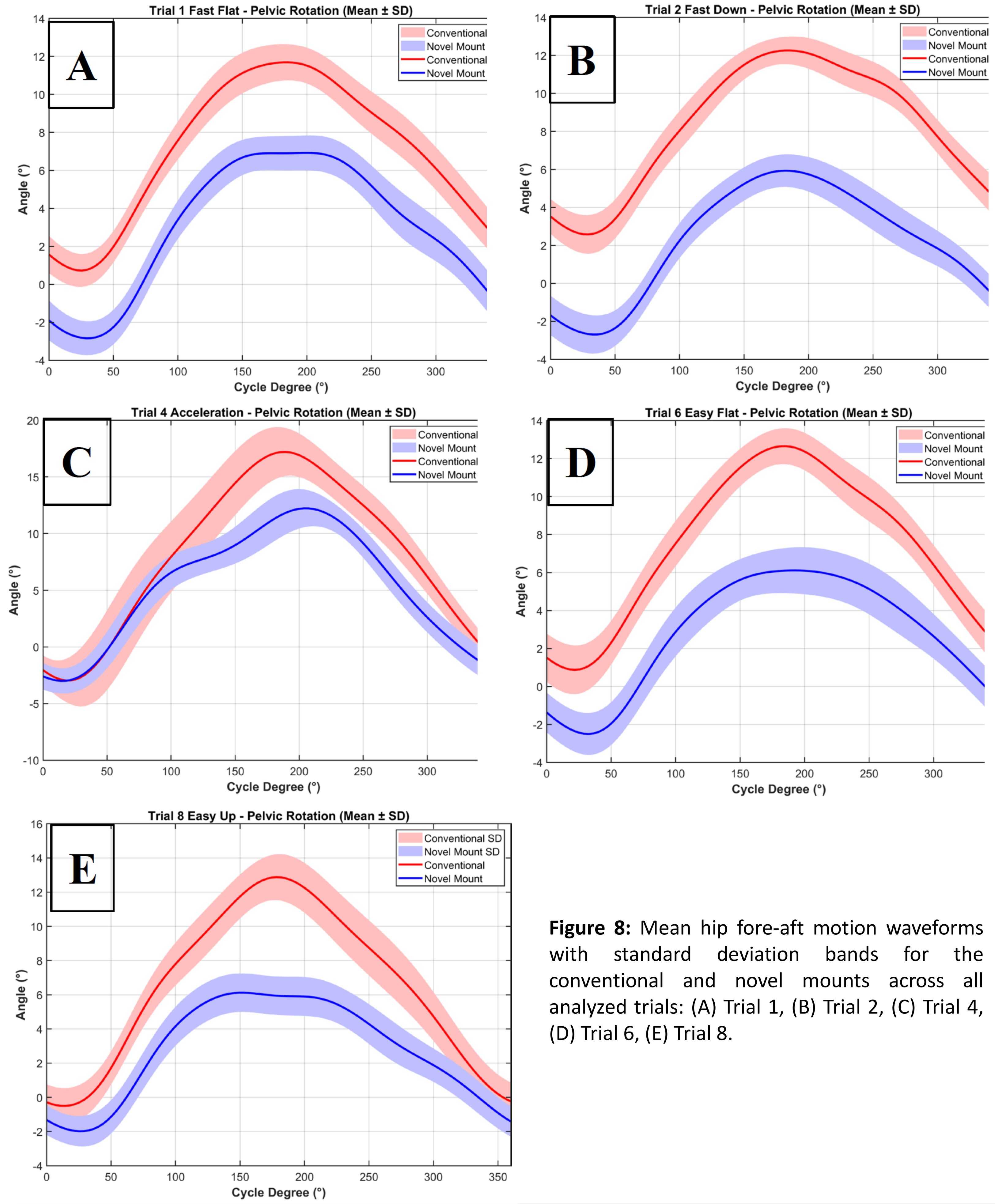

Figure 8: Mean hip fore-aft motion waveforms with standard deviation bands for the conventional and novel mounts across all analyzed trials: (A) Trial 1, (B) Trial 2, (C) Trial 4, (D) Trial 6, (E) Trial 8.

CONCLUSIONS

- The DPI, a novel prosthetic mounting system, demonstrated improved outcomes over the conventional option:
  - Improved load transfer and distribution through prosthetic interface
  - Increased muscular demand in the primary cycling muscle groups
  - Decreased demand in supporting muscle groups
    - suggest a reduction in compensatory motion
  - Overall trend was towards a more efficient cycling behavior

CLINICAL RELEVANCE

- Study supports continued development of the novel technology based on qualitative reports from participant

FUTURE WORK

- Evaluation of DPI mount on a larger population of transfemoral cyclists
- Exploring design improvements identified in the qualitative feedback
- Performing trials in environment outside of lab

DISCLOSURES

- Preliminary study was supported via funding from UNM Rainforest Innovations via a 2024 UNM Health Science and Main Campus Research Collaboration Seed Grant Award