

# Push-off and swing leg knee flexion

## Stiff knee gait in cerebral palsy and simulation model

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**Cerebral palsy (CP):** lesion of the brain that occurs before the 1st year of age, leading to motor impairments

**Stiff knee gait:** gait pattern characterized by reduced knee flexion (velocity) in preswing and initial swing (Fig.1)

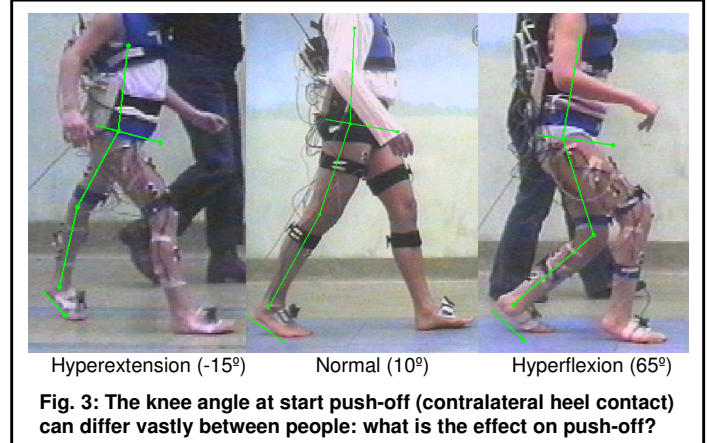
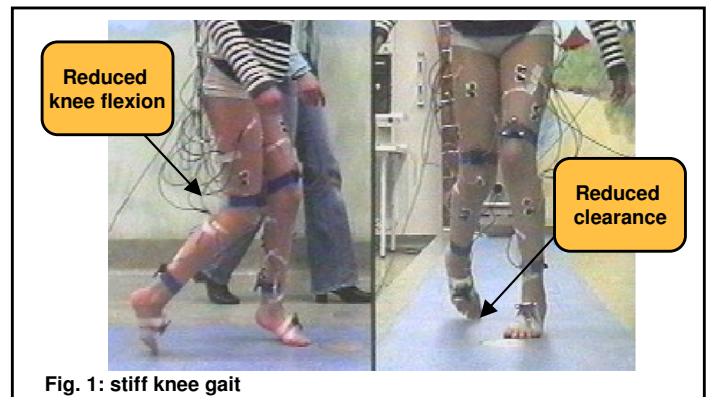
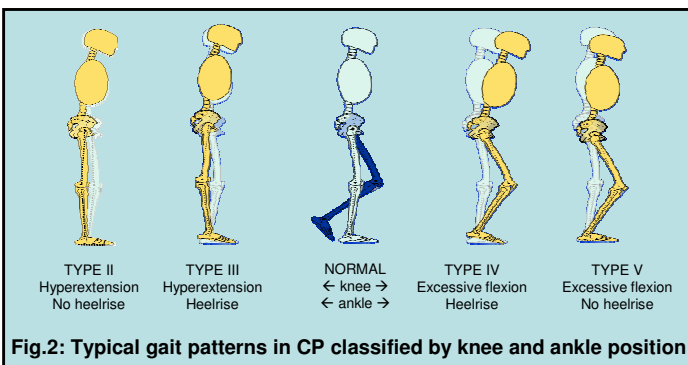
**Problems:** reduced clearance, frequent tripping, small step length and reduced speed

**Possible causes:** spasticity in rectus femoris muscle, reduced push-off, or ineffective push-off

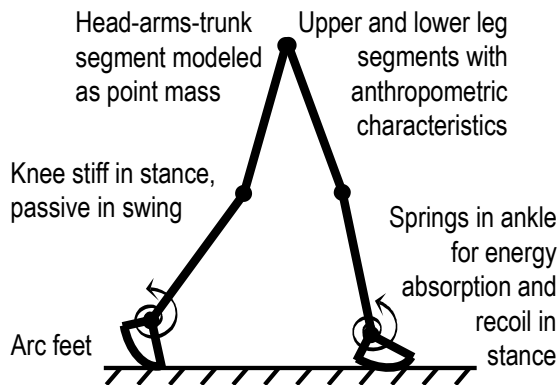
**General question:** what causes stiff knee gait?

**Hypothesis:** leg configuration at push-off plays a role (Fig.2-3)

**Specific research question** How does knee angle at push-off influences the effect (i.e. swing leg knee flexion and kinetic energy) of ankle push-off?



### METHODS



**KIM model** (Our Kind of Interesting Model for KInical Implementation of Modeling)

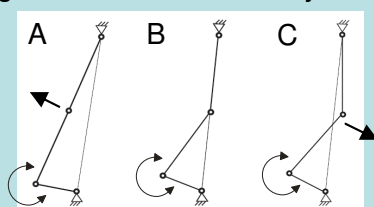
- EOMs derived with 'TMT' methods, solved with ODE45
- Constraints to roll over arc foot, until toe is reached
- Toe modeled as fixed constraint
- Event detection for heel strike, toe strike and toe off
- Cyclic motion can be found by optimizing  $s = \text{OneStep}(s)$
- Stability can be tested with eigenvalues of Jacobian

**This study** • Only one push-off simulated (no limit cycle yet)

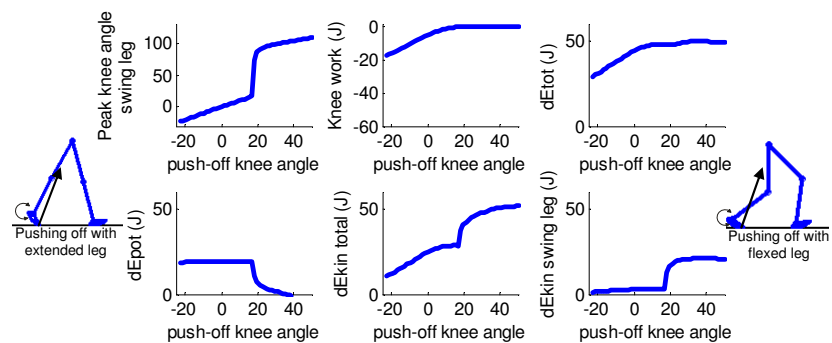
- Starting from stationary position with different knee configurations
- Pushing off with constant ankle push-off (50J), knee passive

#### Hypothetical case: pushing off with ankle moment only

- Knee fully passive and hip and toe fixed
- **A** If knee is behind hip-toe-line, it will hyperextend more
- **C** If knee in front of hip-toe-line it will flex more



### RESULTS (so far): Leg configuration matters!



- Pushing off with a more flexed knee results in more knee flexion in swing and more kinetic energy (Fig4)
- There is a bifurcation point where knee crosses hip-toe-line

**CONCLUSIONS** • Accurate control of the leg configuration seems essential for effective push-off  
• Swing leg knee flexion in CP may be decreased due to hyperextended gait

**Discussion** • Knee is passive (stiffness/damping = 0): what is the effect of different knee control options?

- In humans, many interacting factors influence push-off (muscle length/velocity, strength, control) – what is their role?
- Do the found effects hold when simulating stable limit cycle gait in different configurations?
- Pushing off with straight leg and ankle powering alone results in limited knee flexion in swing and clearance problems  
→ some knee or hip moment during push-off is necessary!