Effectiveness of Hinged Crank Arms in Cycling Concerning Knee Flexion Limitations

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How this all started:

• A young man with a rotationplasty said he wanted to bicycle.
• Knee flexion angle was 90° at best. (110° needed)
• Is there a bicycle modification that will help him out?
Compensation Strategies

• Standing while pedaling
• Removing the affected limb from the pedal when it reaches the unachievable portion of the cycle
• Hip hiking
Key Terms

• Crank Arm – lever arm that transmits torque from the pedal to the wheel hub

• Force Asymmetry (Sanderson, 1990)
  – Difference in the contribution of each leg to the total force used on the pedal
  – Can show weaknesses between legs

• Work Asymmetry (Sanderson, 1990) (Daly and Cavanagh, 1976)
  – Difference in the contribution of each leg to total work
  – Can show differences in each leg’s ability to direct force on the pedal
Bicycle Parts

- Pedal
- Crank Arm
- Spindle
Adapting the Bicycle to the Person

- Hinge Crank Arm
- Short Fixed Adaptor
- Passive Peg
Hinged Crank Arm

• Accommodates a ROM limitation
• Variable crank arm length
• Requires more effort than a standard bike crank (Shan, 2008)
Short Fixed Crank Arm

- Less expensive option than the hinged crank arm
- Fixed length shorter than a standard crank arm
Hypothesis

Pedaling **Asymmetries will increase with** the mechanical complexity of the bicycle crank system.
Methods

• Tested hypothesis with three conditions
  – Standard bicycle cranks arms on both limbs
  – Shorten fixed crank arm on the affected limb
  – Hinged crank arm on the affected limb
Methods

• 5 Subjects
  – 4 Intact
  – 1 Amputee
    • Rotationplasty
  – Age Range 14-37
  – 3 male : 2 Female
Methods

• IRB Approval
• Subjects consented to participation
• Anthropometric data was taken
• Subjects were asked to ride a stationary bicycle adjusted to their measurements
• 3 Trials involving 3 different crank arm conditions at 75 watts of resistance and a cadence of 60 RPM
  • Standard Crank Arm
  • Short Fixed Crank Arm
  • Hinged Crank Arm
Data Collection

- Kinematic data was collected using Peak Motion Capture System
- Pedal force data was collected using Piezoelectric element force pedals
Result: Rotationplasty

- Knee Flexion limited to 90°

- Hinged Crank Arm is the only modification that will accommodate the limitation
Results: Work Asymmetry

![Graph showing work asymmetry for amputee and mean intact subjects. The graph indicates that the amputee subjects have significantly higher asymmetry compared to the mean intact subjects. The standard deviation is within the range of 0% to 20%. There is no significance for these trials as indicated by p ≤ 0.05.]
Results: Force Asymmetry

<table>
<thead>
<tr>
<th>Asymmetry</th>
<th>Amputee</th>
<th>Mean Intact</th>
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</thead>
<tbody>
<tr>
<td>20%</td>
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<td></td>
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<tr>
<td>10%</td>
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<tr>
<td>40%</td>
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<tr>
<td>50%</td>
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</tbody>
</table>

p≤0.05 No significance for these trials
Discussion: Work Asymmetry

- Closer to zero means that legs shared the load
- More asymmetry means the dominant leg is more likely to fatigue

$p \leq 0.05$ No significance for these trials
Discussion: Force Asymmetry

• Some asymmetries may be the norm (Sanderson, 1990)
  • Consequences in performance
• 10% Asymmetry norm for intact subjects (Childers, in review)

\[ p \leq 0.05 \text{ No significance for these trials} \]
Conclusion-esque

• No statistical significance = No real conclusions
• Hypothesis was rejected for intact subjects
  – Hinge Crank Arm as a more complex crank system showed less asymmetry than rigid fixed systems
• Amputated subject could not be determined
  – Only accomplished one condition
Clinical Relevance

• Cycling is a valuable
  – Rehabilitation tool
    • Impact mobility, activity, and participation
  – Improve quality of life
    • Social Development
    • Typical Childhood

• Using a bike modification would allow those with limitations to utilize cycling as a form of exercise and rehabilitation.
Limitations

• Limited subjects
  – 5 subjects
  – Only 1 subject with a rotationplasty fit the criteria
Future Studies

• Comparing compensation strategies:
  – Standing pedaling
  – Hip-hiking
  – Hinged Crank Arm

• Provide insight
  – Benefits of each strategy
  – How someone chooses a certain strategy
Acknowledgements

- **Lee Childers** (Likened to the Norse God Odin, who did smote the Danish Army at the Battle of Lena in 1208)
- Rob Kistenberg
- Geza Kogler
- Rob MacDonald
- Classmates
- Subjects
References

Questions?
More on Asymmetry

(Sanderson, 1990)
• Work Asymmetry more pronounced at lower power outputs and increases with increased cadence. (Sanderson, 1990)
• Some asymmetry is to be expected due to differences in anatomy, strength, and handedness, as well as differences in independent control.

Daly and Cavanagh, 1976
• Asymmetry in work output is typical of cycle ergometer pedalling.
Crank Cycle

- **Top 315°-45°**
  - Forward Force
  - Prepare for Power Phase
- **Power 45°-135°**
  - Produce power to overcome force of pedal and lift contra-lateral leg in recovery
- **Bottom 135°-225°**
  - Inertia moves limb rather than muscle activation
- **Recovery 225°-315°**
  - Negative power (Absorbed)
  - Pedal clears the bottom and ascends back toward top dead center (TDC)
Calculate Speed

- http://bike.smxus.com/cadence.asp
- 0.08 X Front Chain Ring Teeth/ Sprocket Teeth = MPH
- Shan, 2008
  - 100 RPM = 20 MPH
  - 60 RPM = 12 MPH
Clipless Pedal v Clipped Pedal