

# Effect of Pushrim Compliance on Propulsion Efficiency

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# Background



Wheelchair users depend on their upper extremities for **mobility**

Upper extremity **pain** and injury lead to a loss of function and therefore a loss of mobility and independence

# Upper Extremity Pain

High incidence of upper extremity pain

64% of 239 wheelchair users (Sie 1992)

68% of 84 wheelchair users (Gellman 1988)

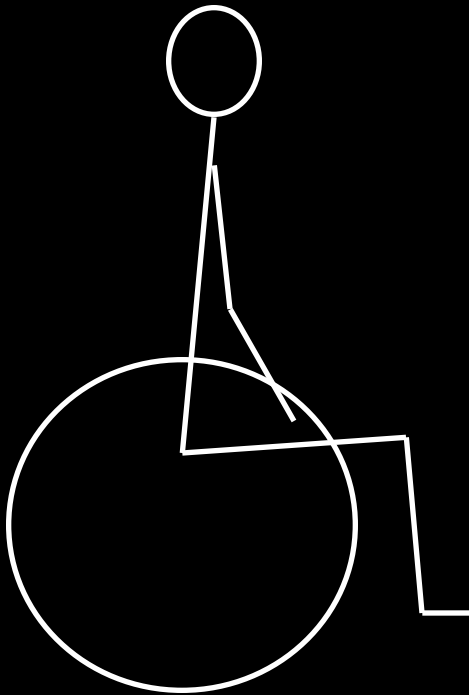
Most common at the wrist and shoulder

Carpal Tunnel Syndrome - wrist

Impingement Syndrome - shoulder

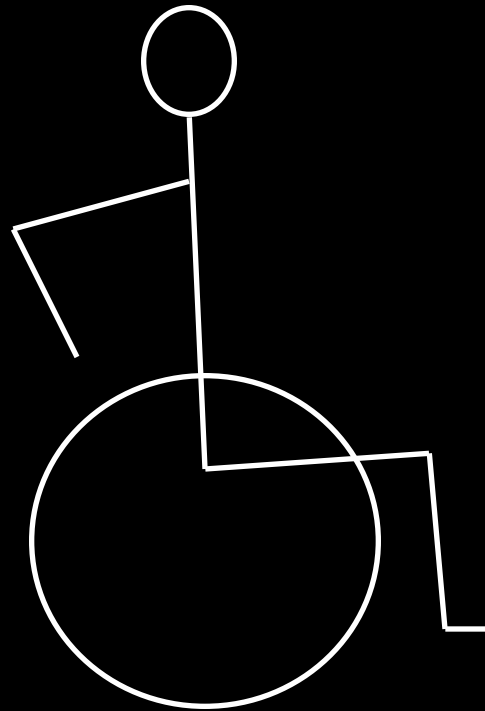
# Impact During Propulsion

1



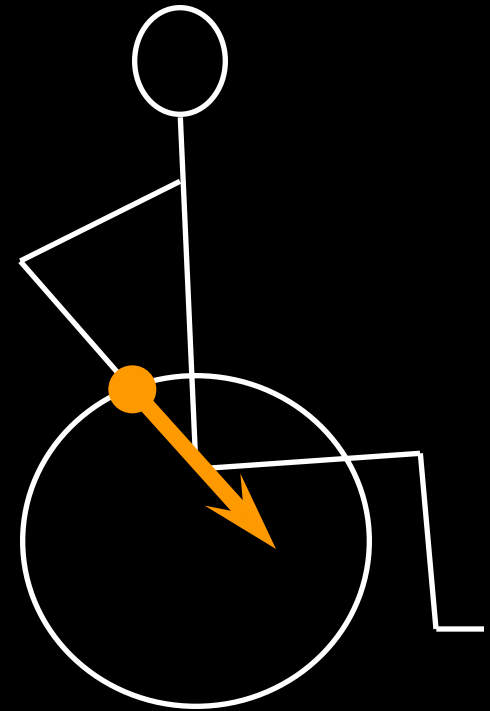
End of Push

2



Reach Back

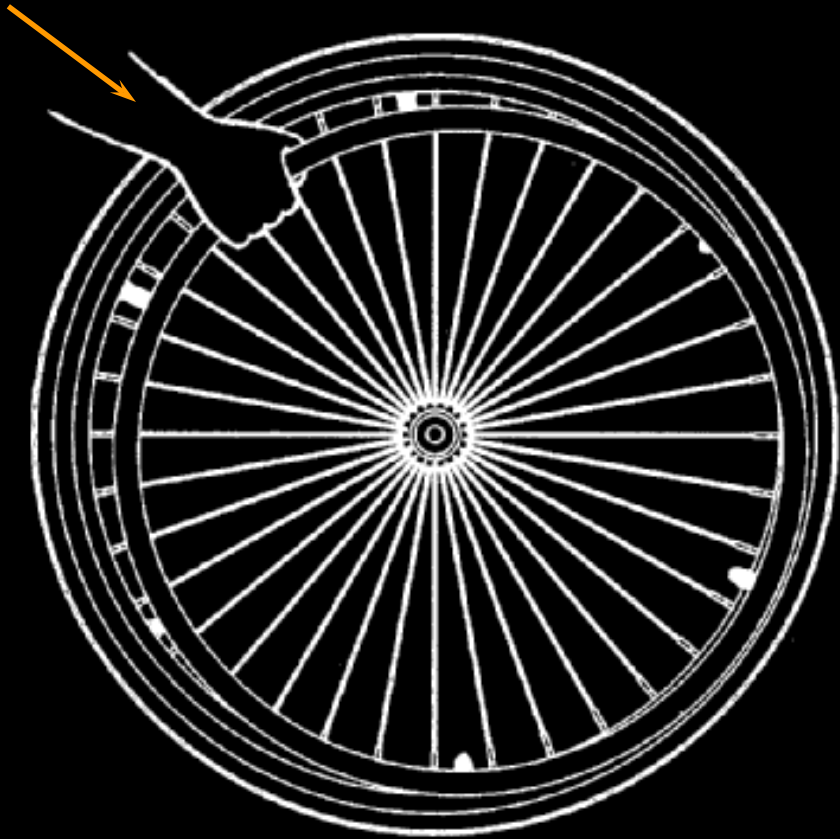
3



**IMPACT**

# Low Impact Pushrims

**Impact**



Reduce impact stresses by allowing the pushrim to displace relative to the wheel when impacted by the hand

# Relative Mechanical Efficiency of Low Impact Pushrims (Richter 1998)

Not all of the energy absorbed by the pushrim during impact is returned to the wheel during the push



# Potential Benefit in Efficiency due to Pushrim Compliance

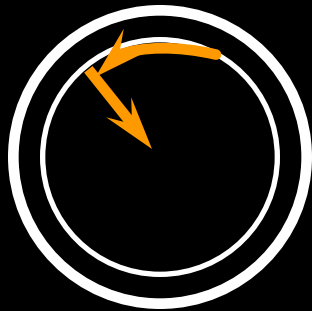
Increased degrees of freedom of the pushrim reduce mechanical constraints on the upper extremity during propulsion

Increased freedom of movement of the arm may allow the user to better optimize propulsion technique

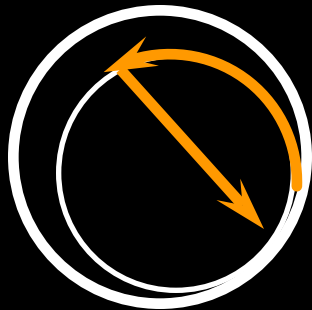
# Research Question

What are the net effects of pushrim compliance on the metabolic demands of the wheelchair user during propulsion?

# Three Unique Designs Investigated



= Shock Mount



= Extension Spring



= Bungee Cord

# Exercise Task

5 subjects (1 female; 4 males)

Subjects pushed wheelchair on stationary dynamometer at a self-selected speed using rigid and compliant pushrims for 3 minutes

Dynamometer resistance set to simulate propelling on both a 2% grade incline and a 3.3% grade incline

# Metabolic Response

Physiologic measurements of ventilation, oxygen consumption and heart rate taken

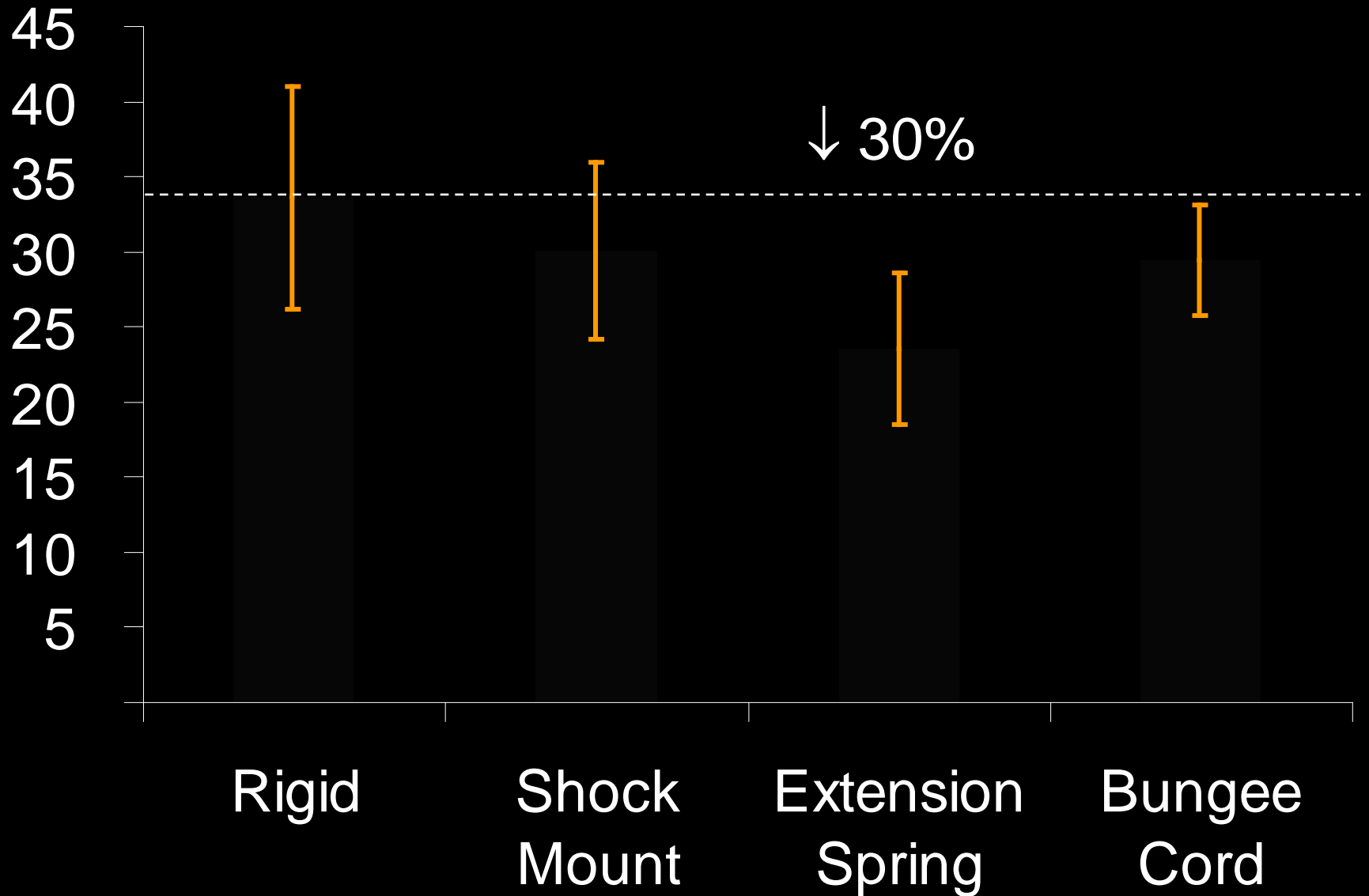
Response during the final minute of exercise used for comparison

# Analysis

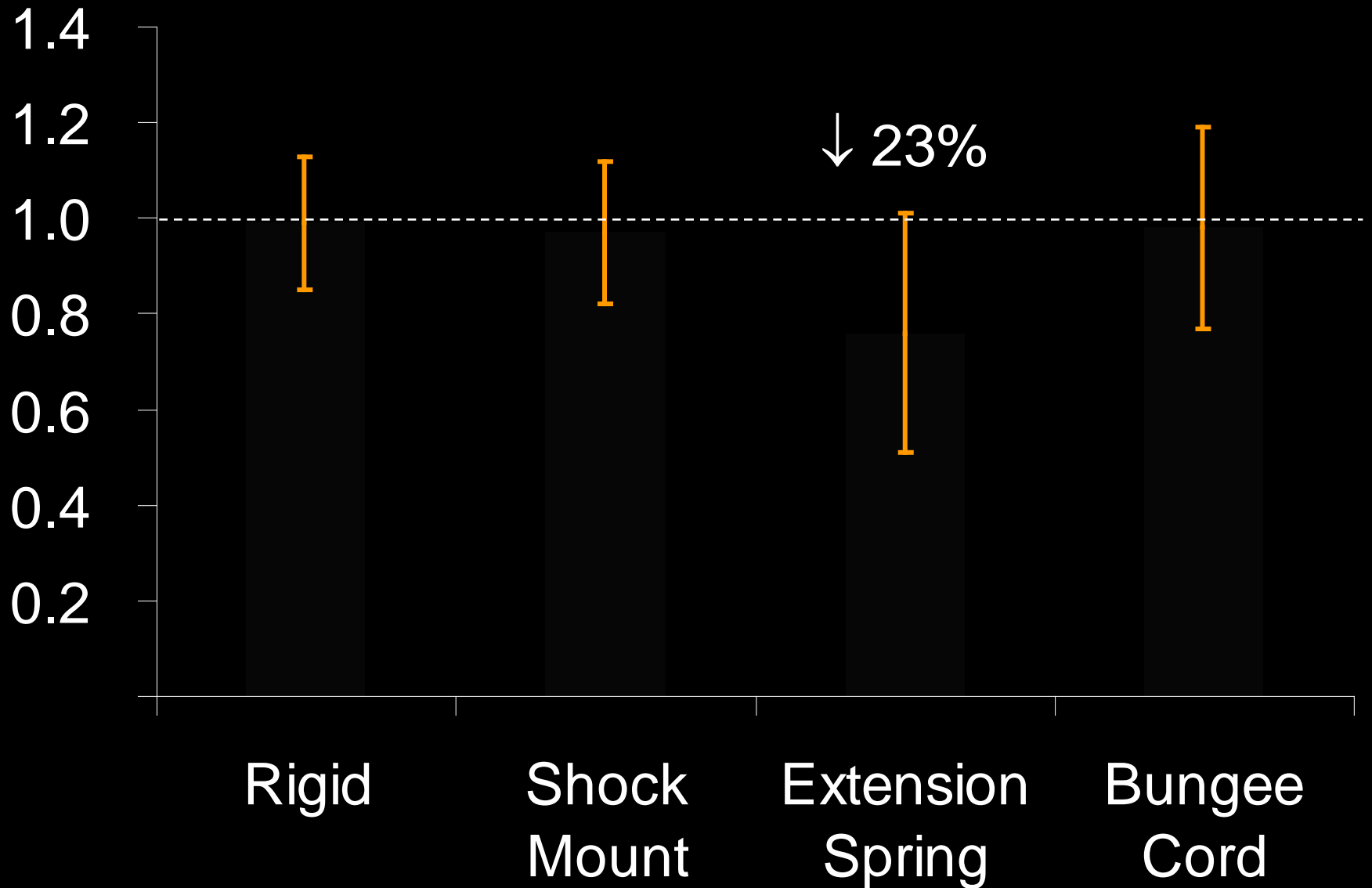
Efficiency indicator defined as the ratio of average propulsion velocity to oxygen consumption

Results compared using 2-tailed paired sample t-test, considered significant if  $p < 0.05$

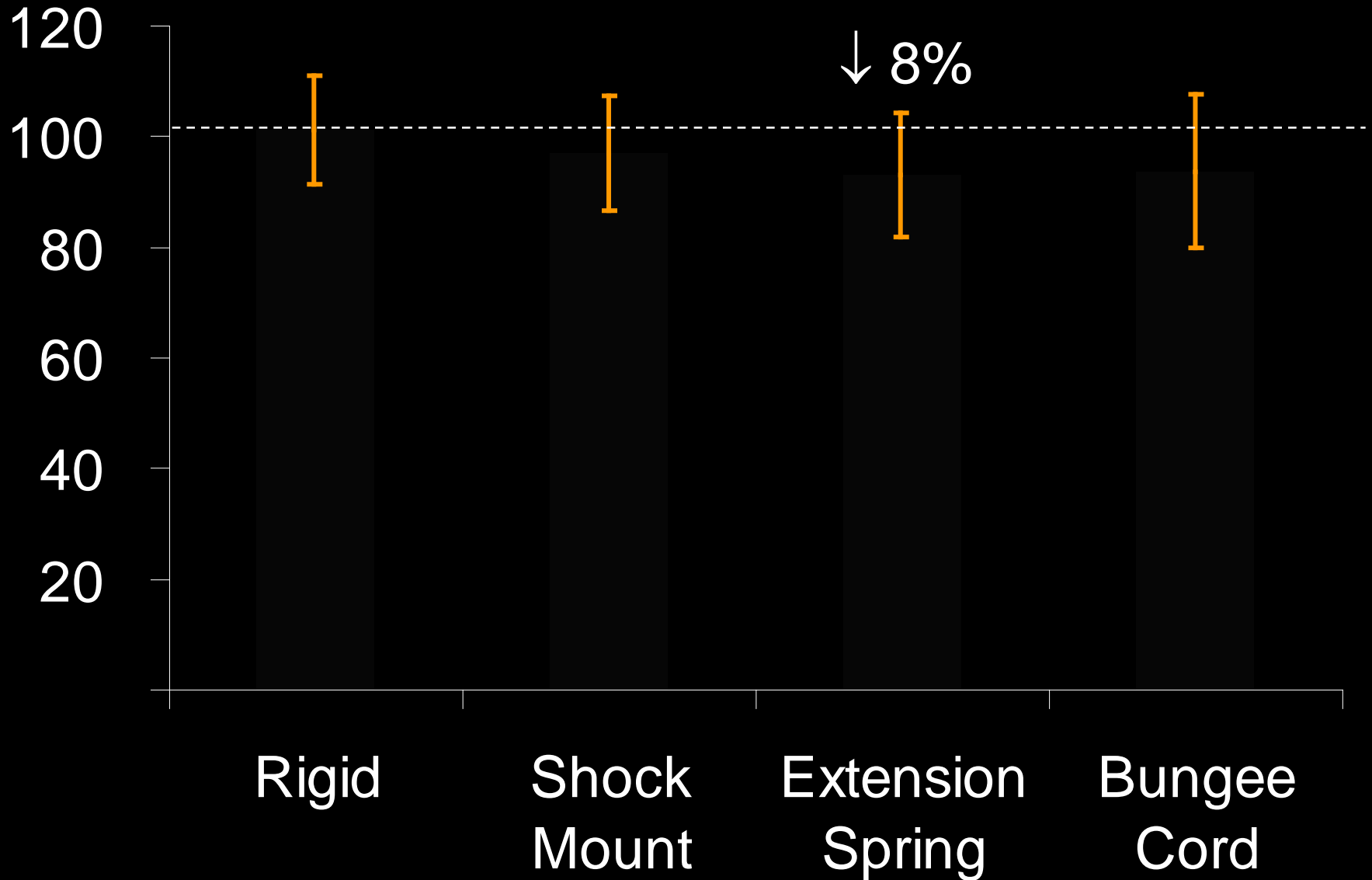
# 2% Grade: Ventilation (L/min)



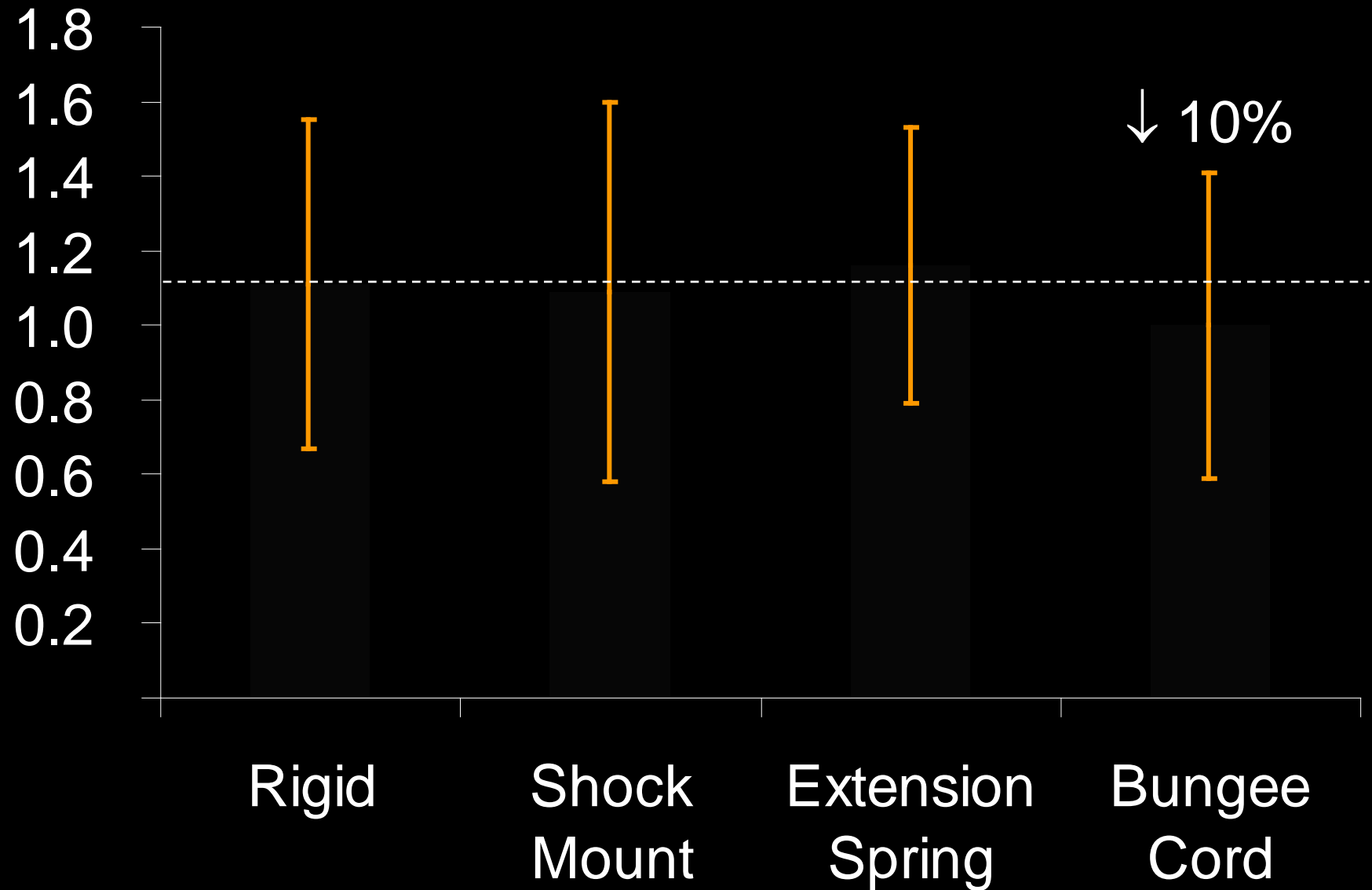
# 2% Grade: O<sub>2</sub> (L/min)



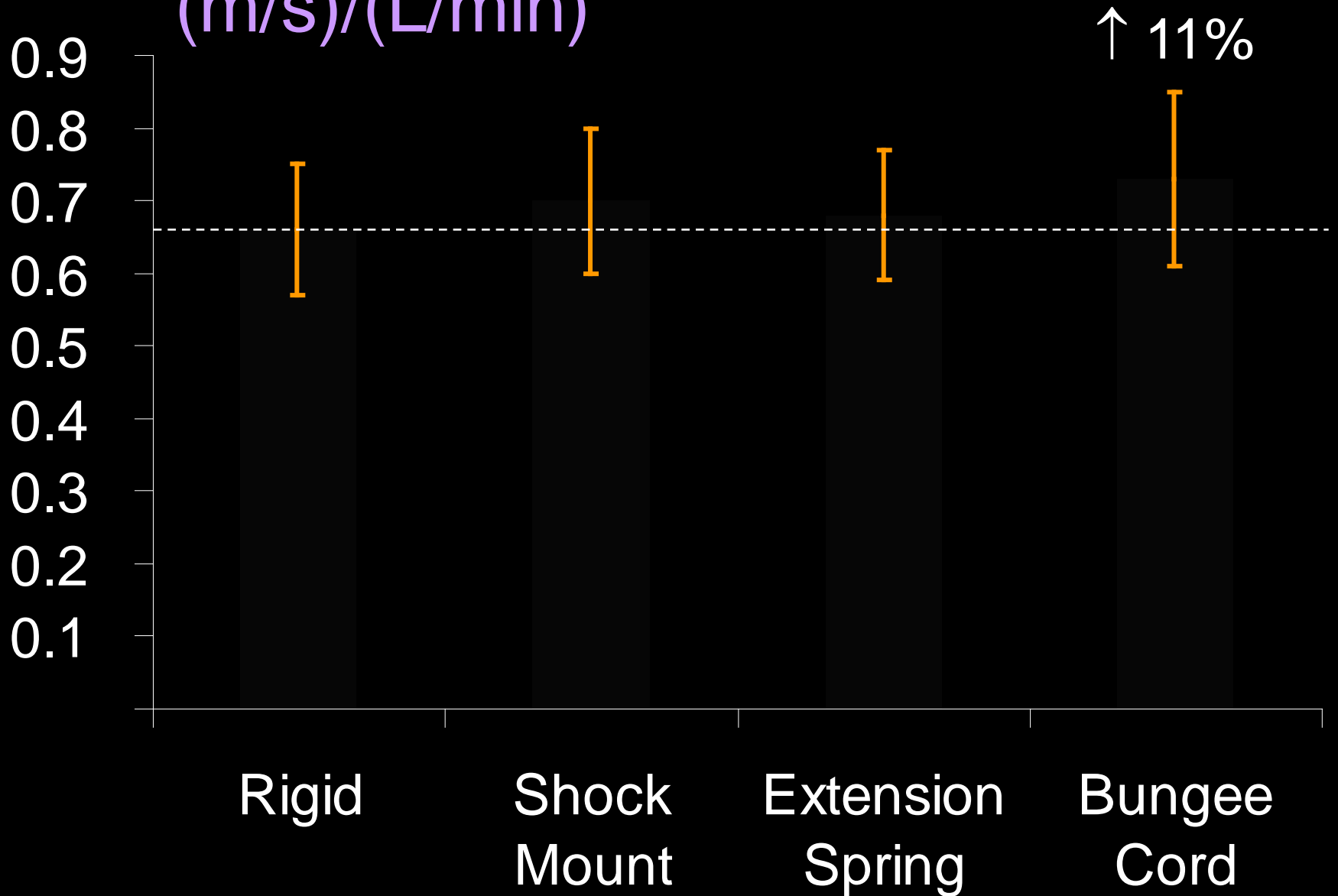
# 2% Grade: Heart Rate (b/min)



# 3.3% Grade: O<sub>2</sub> (L/min)



# 3.3% Grade: Efficiency Indicator (m/s)/(L/min)



# Discussion

Pushrim compliance tends to reduce rather than increase metabolic demand

Dynamic model will be created to investigate underlying effects of compliance on mechanical advantage of arm with modified kinematics

Results will allow designers to optimize compliance characteristics

# Acknowledgments

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# Questions