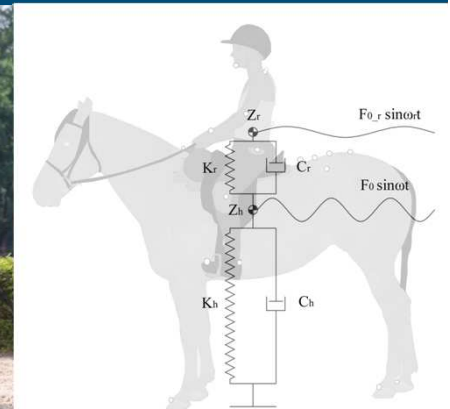




# Biomechanics of horse-rider interaction

Patricia de Cocq



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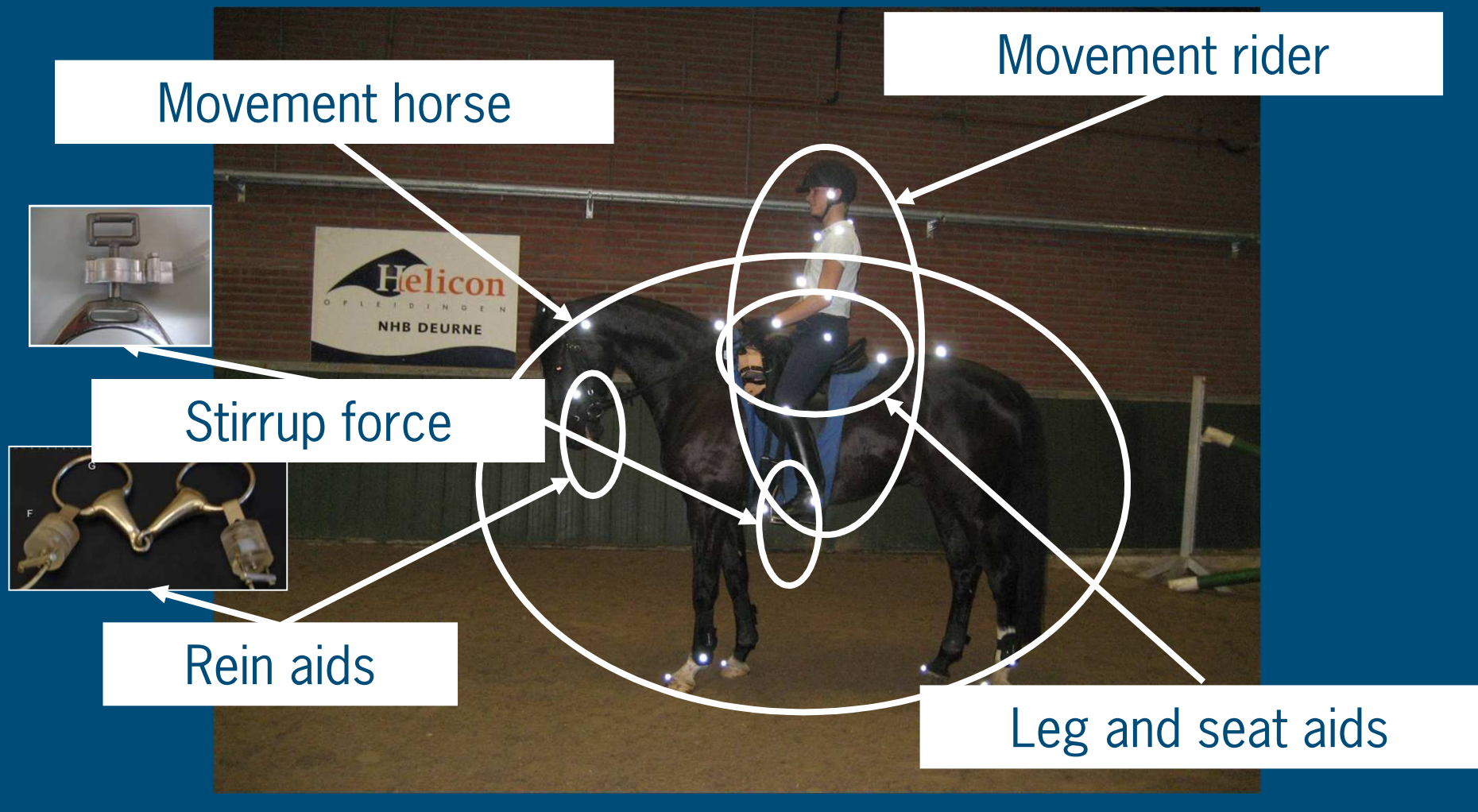
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# Outline of presentation

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- Introduction: history of research on horse-rider interaction
- Biomechanical interaction through the saddle
  - Influence of weight of the rider
  - Influence of riding technique/position

# Introduction: interaction horse-rider

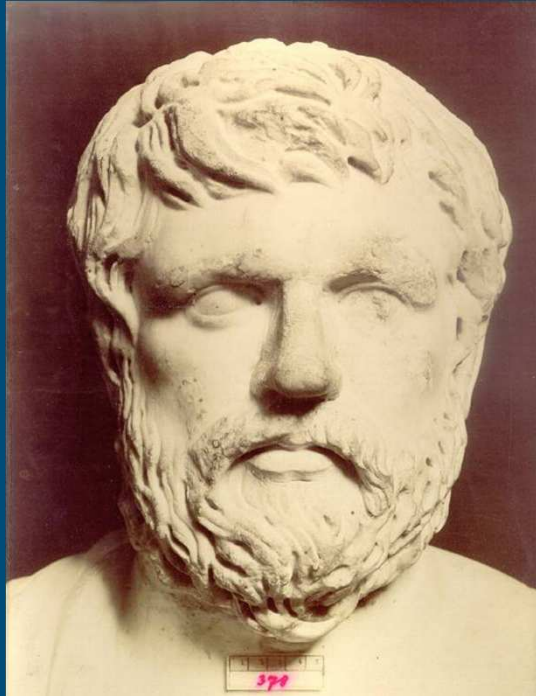


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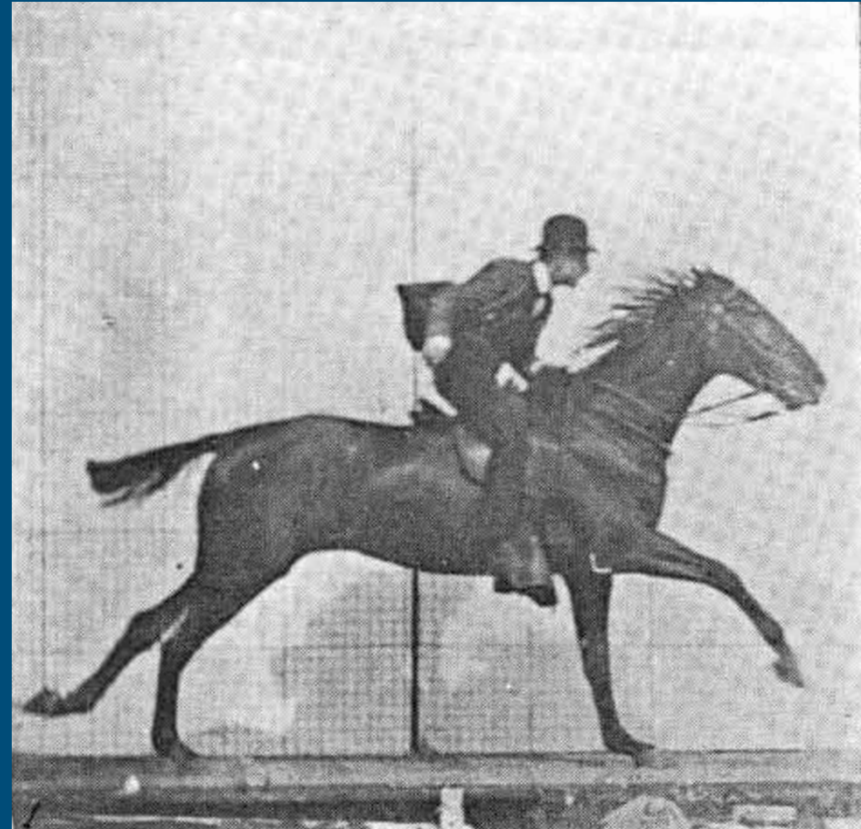
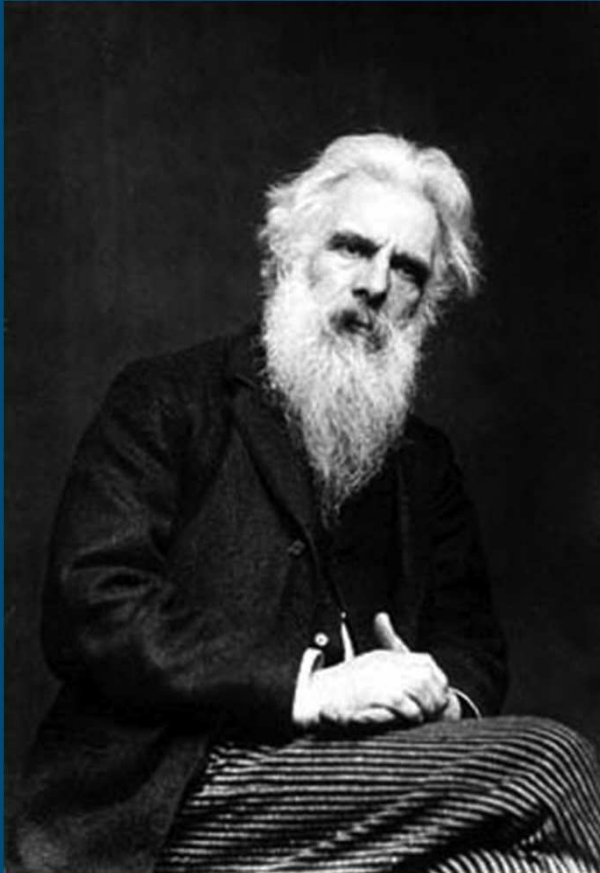
# Introduction: Xenophon (431-354 BC) – Peri Hippikes



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# Eadweard Muybridge (1830-1904) – Animals in motion

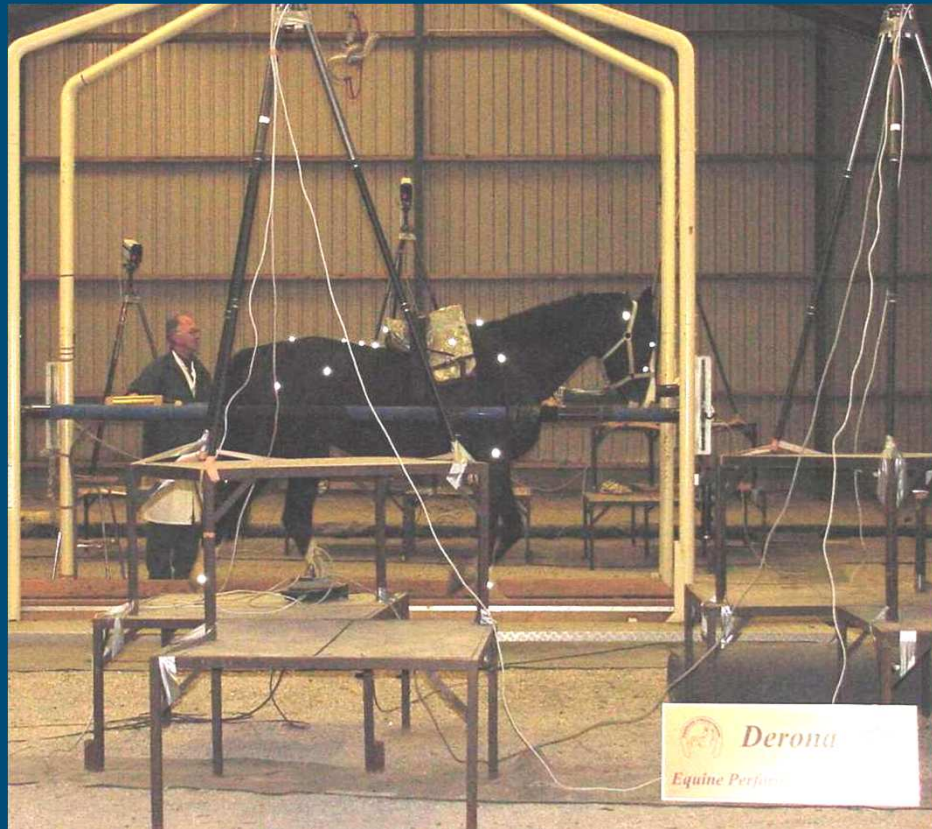


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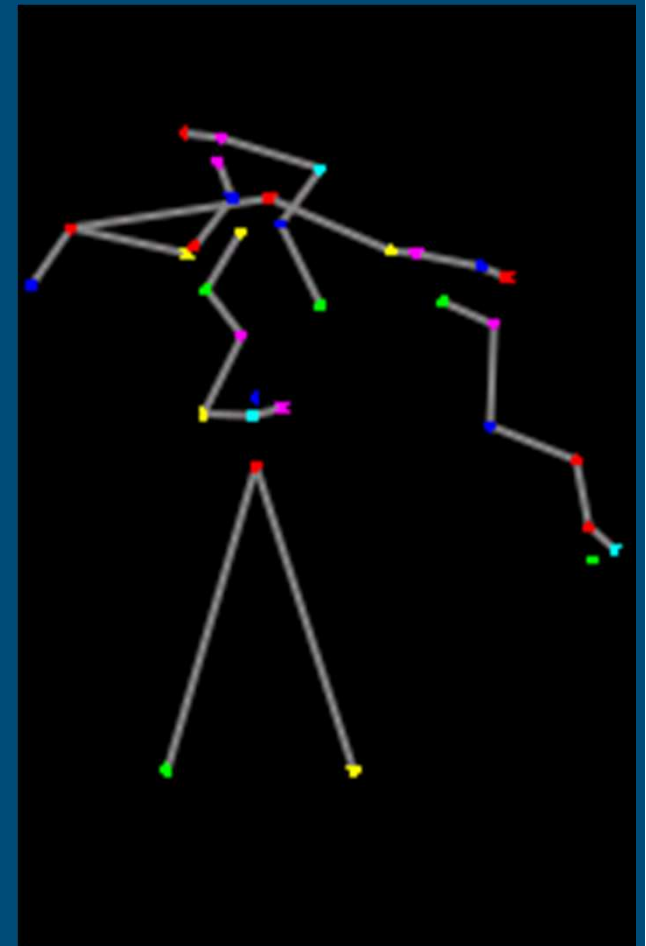
# Introduction: research in laboratorial setting



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# Introduction: research in field conditions



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# Load carriage mechanisms in equine species



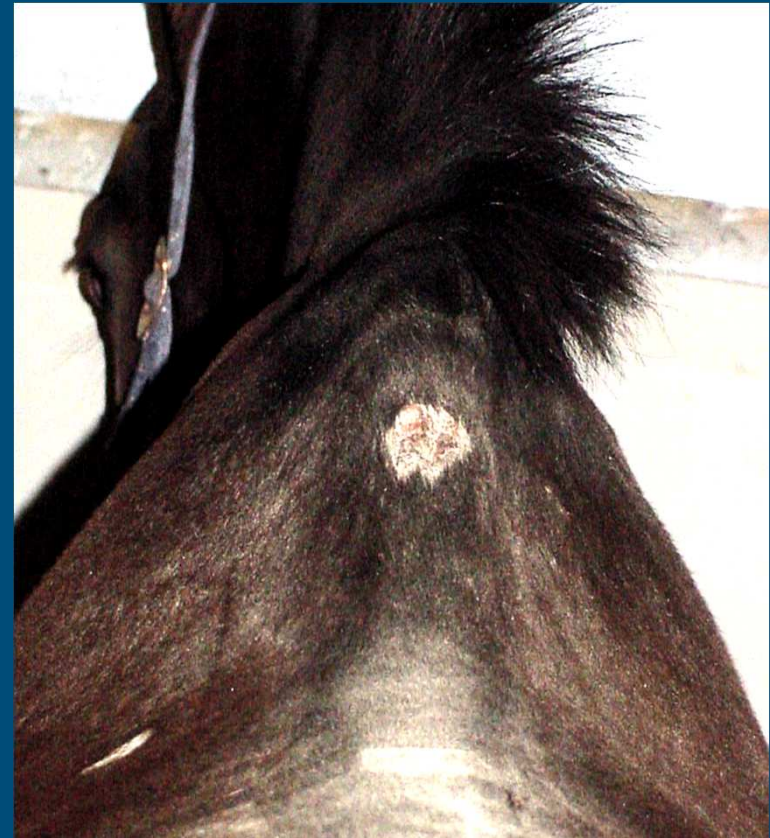
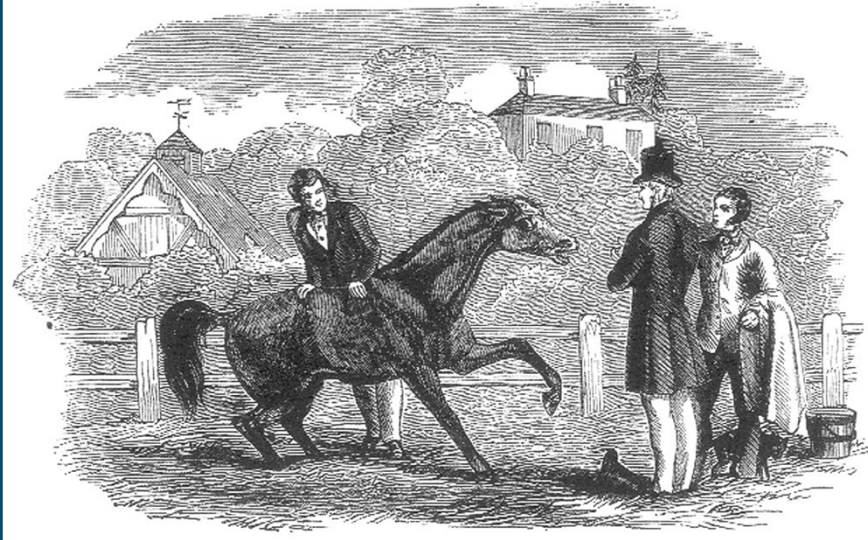


# Load carriage mechanisms in human





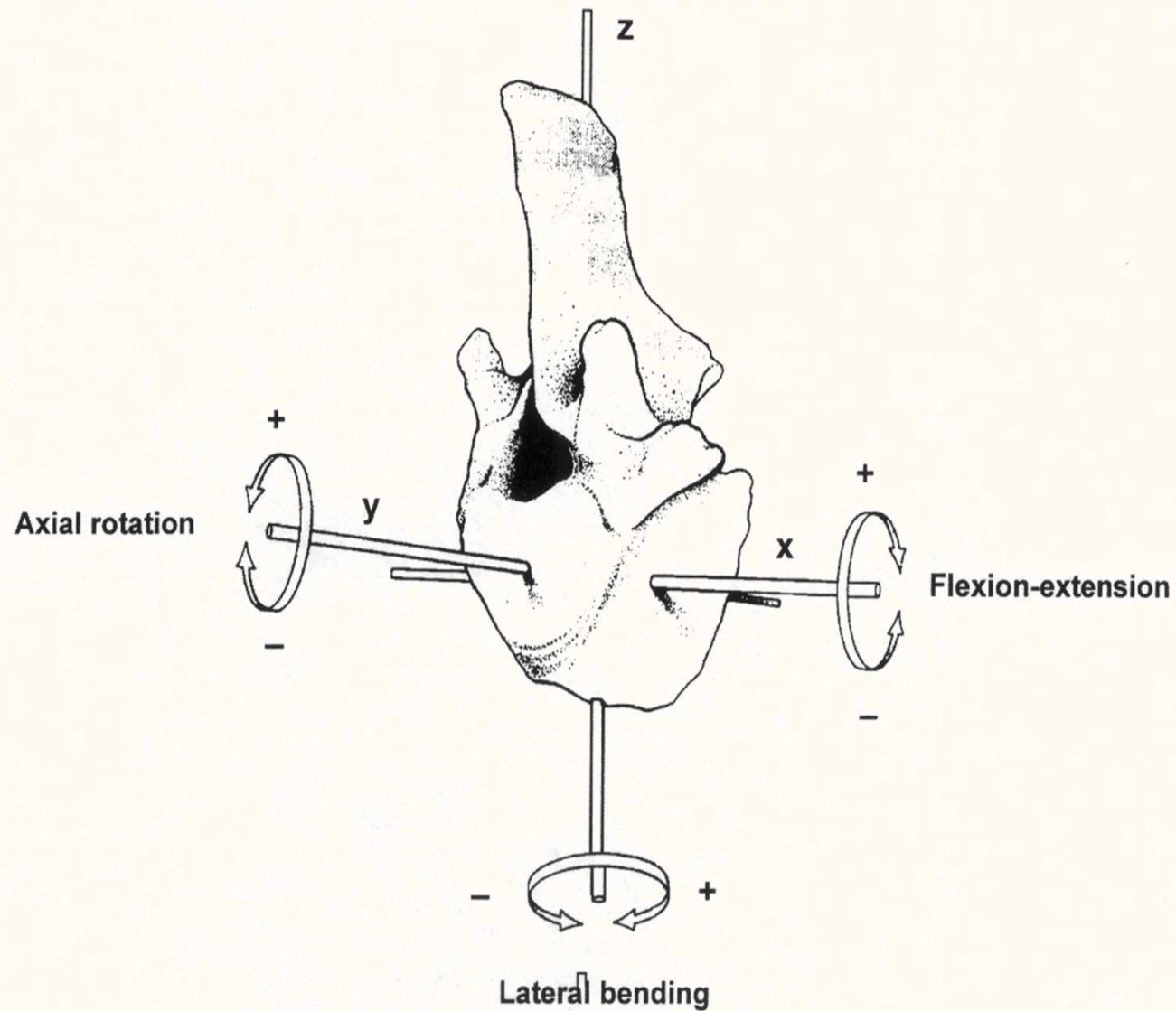
# Influence of weight of the rider on the horse



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Unloaded



Lunging girth



Saddle



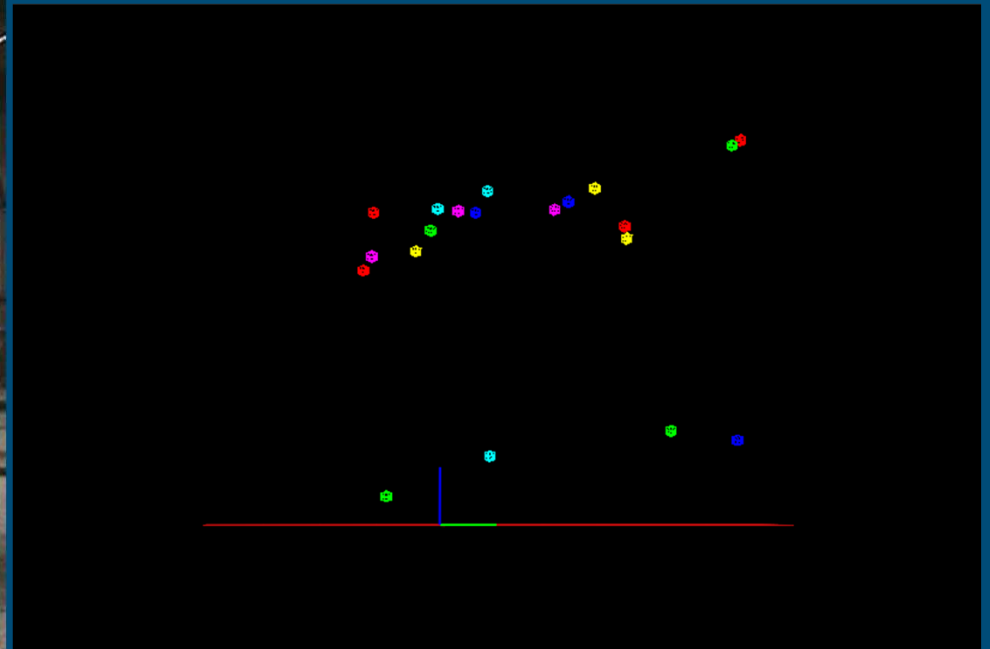
Saddle with  
weight



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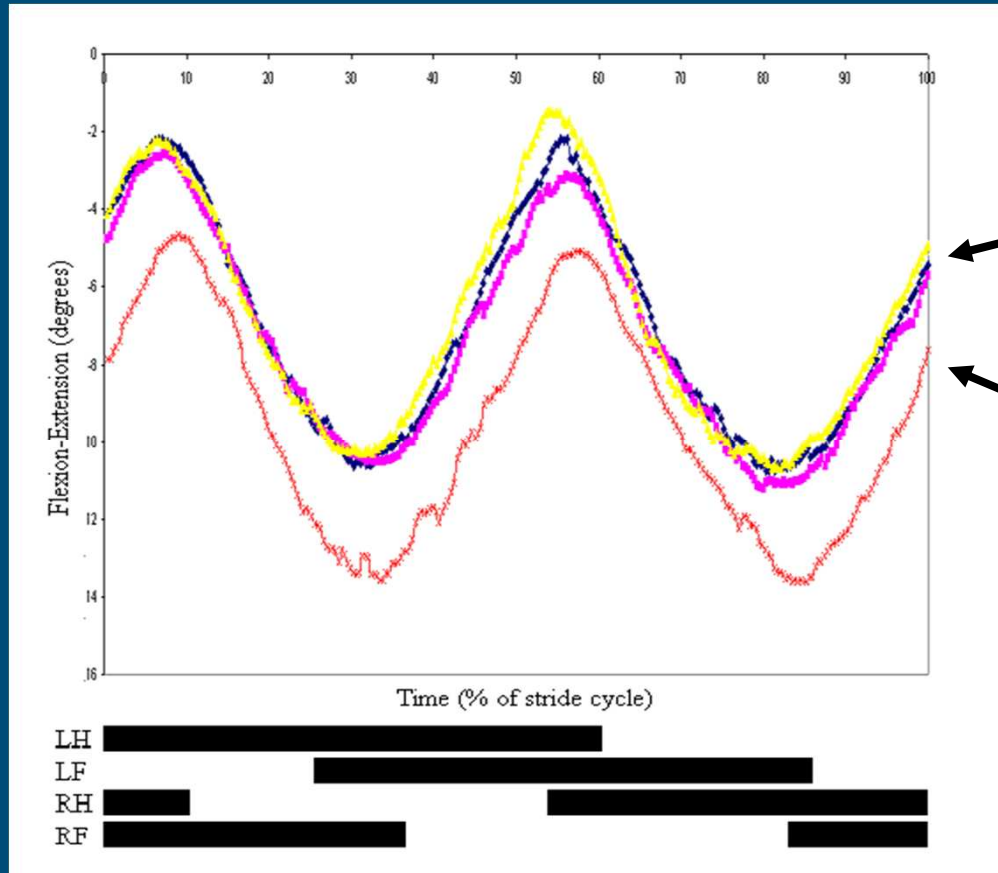




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# Influence weight on back kinematics horse



Other situations

With weight



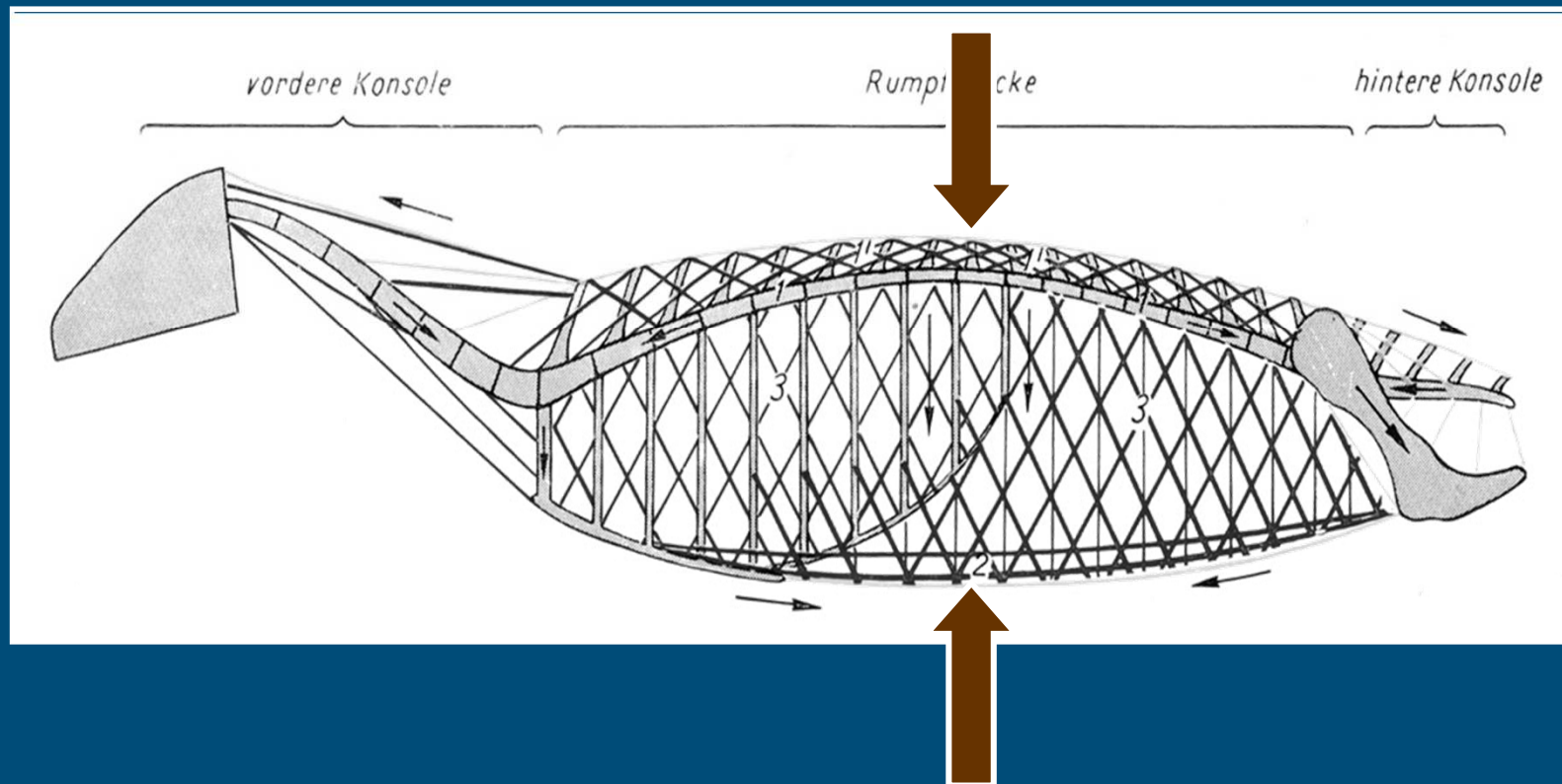
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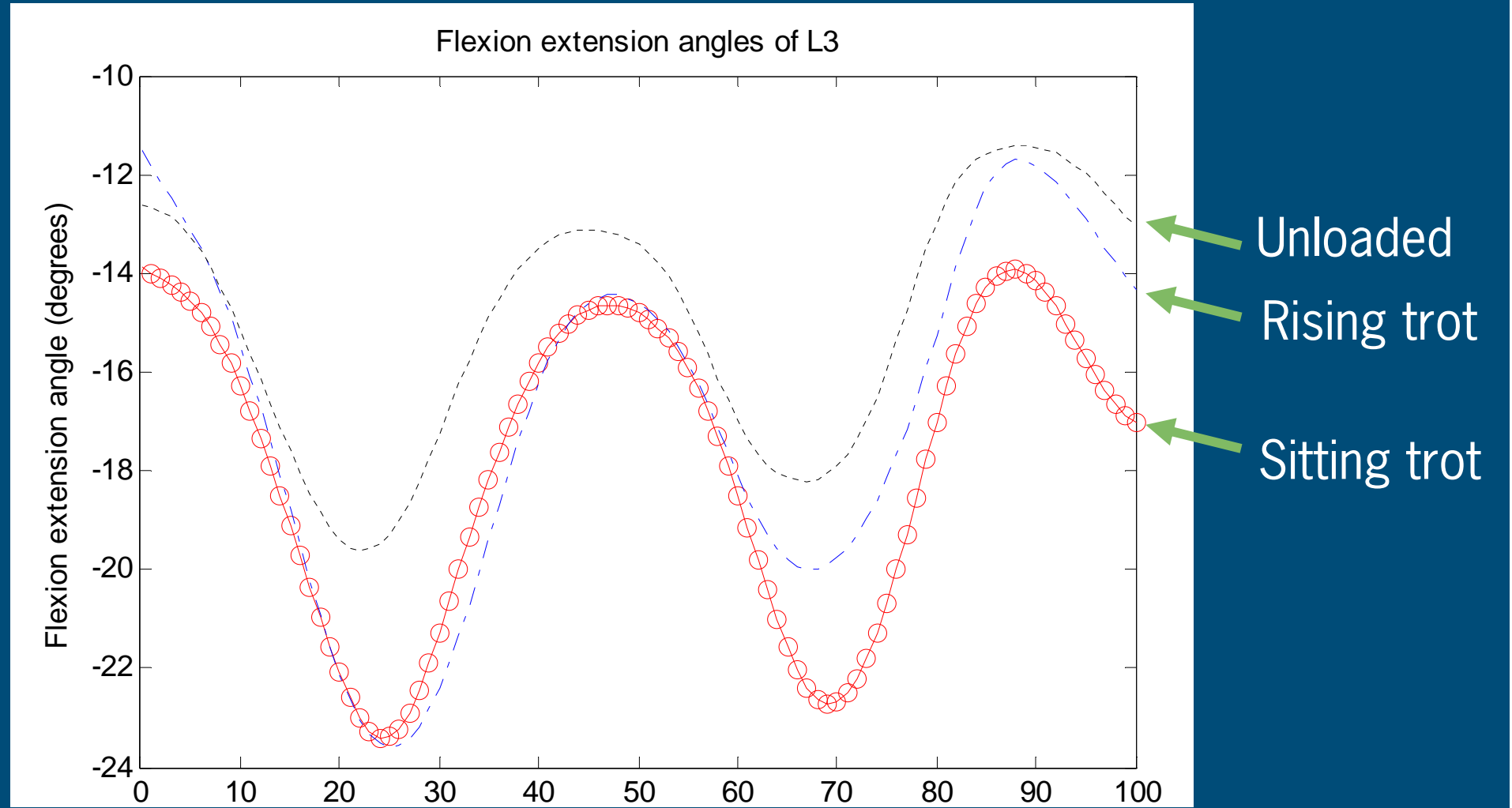


# Biomechanical concept back movement

- Bow-and-string concept (Slijper 1946)



# Experiment with real rider





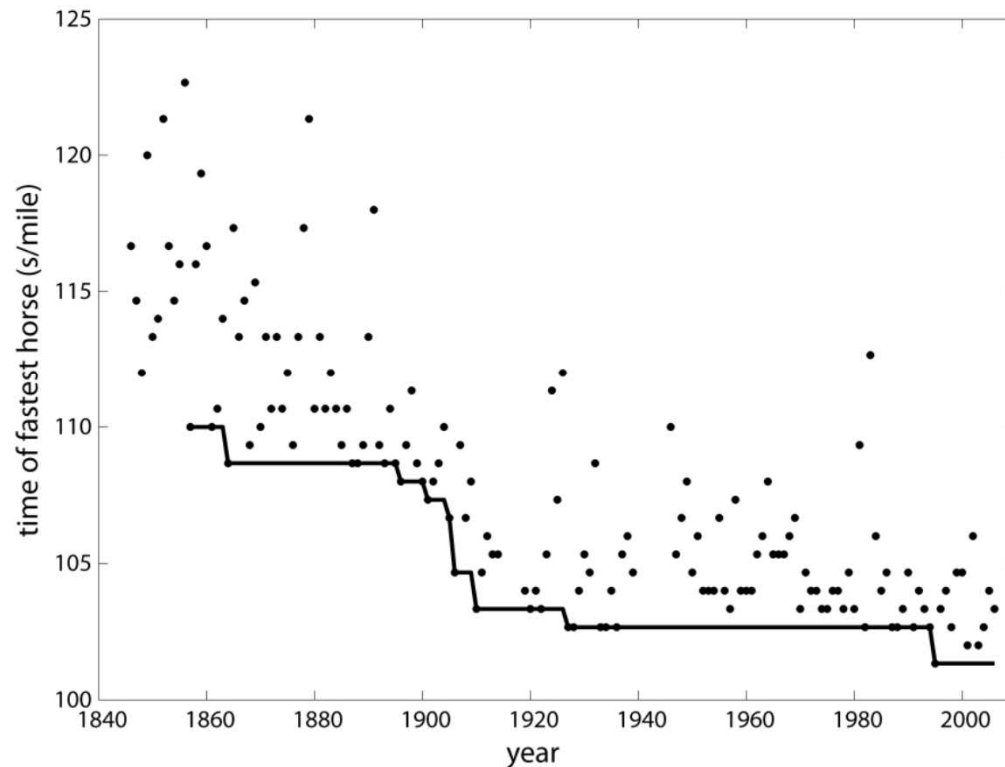
# Influence of riding technique and rider position



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# Effect position jockey on speed horse



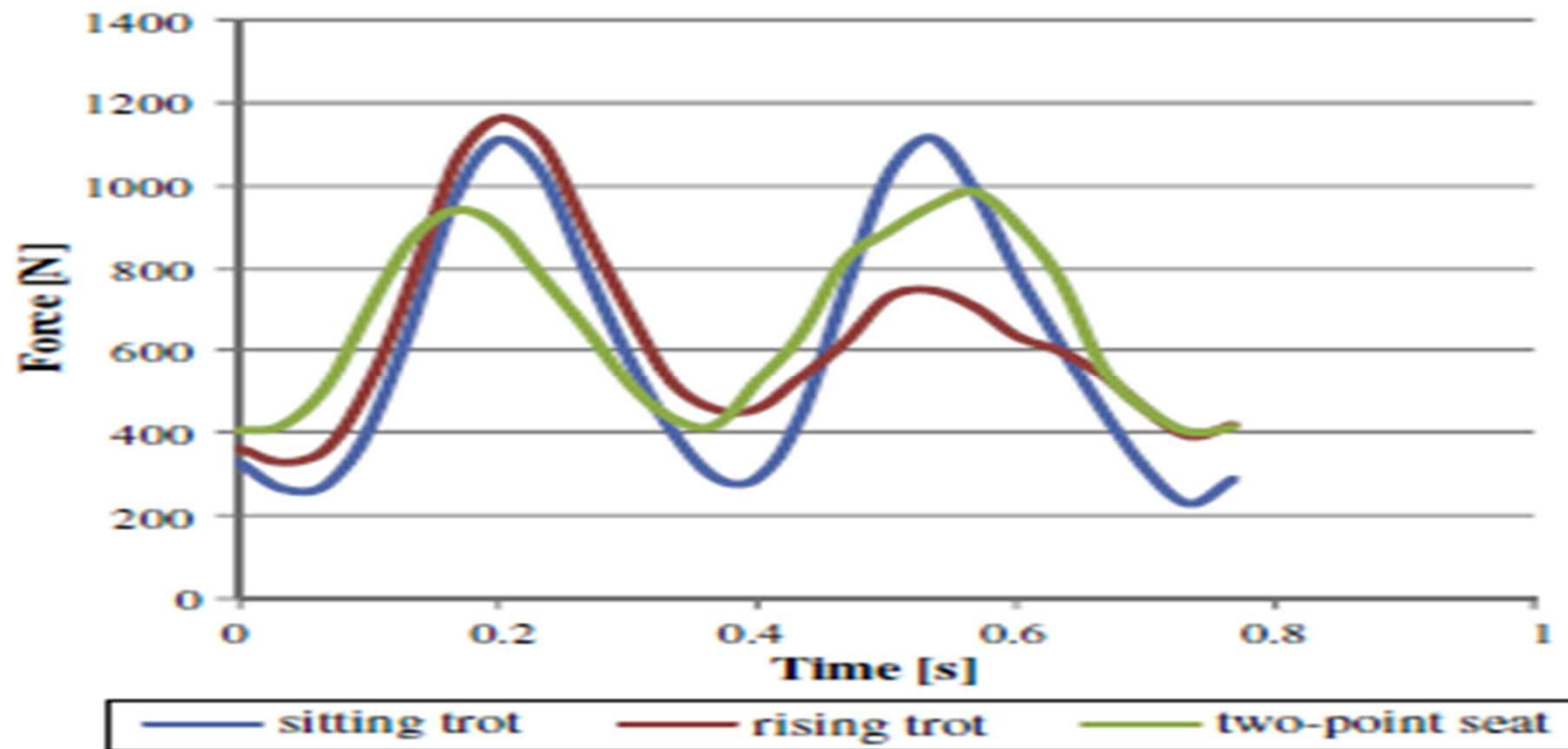
Reduction peak vertical force of rider: Racing horses (Pfau et al. 2009)



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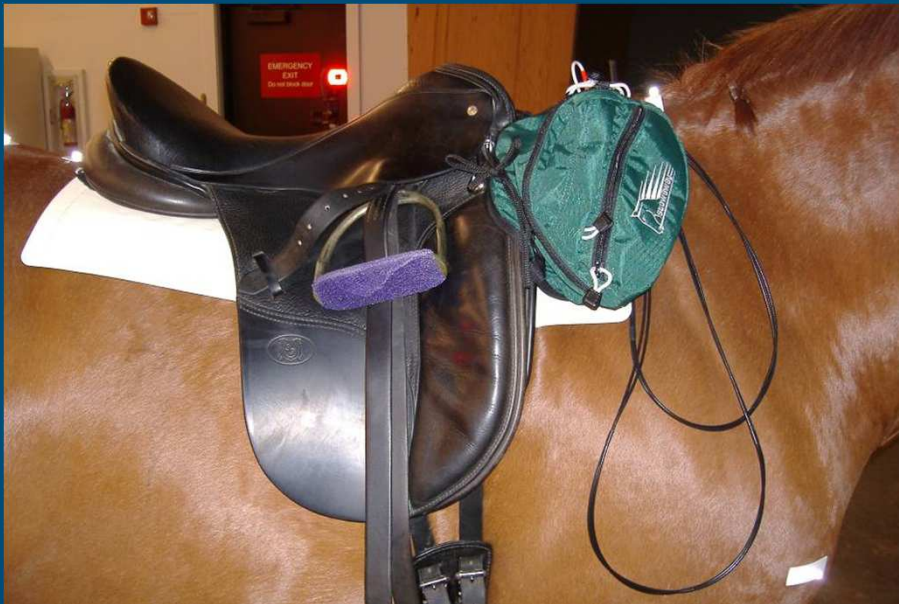
# Influence sitting, rising trot and two-point seat



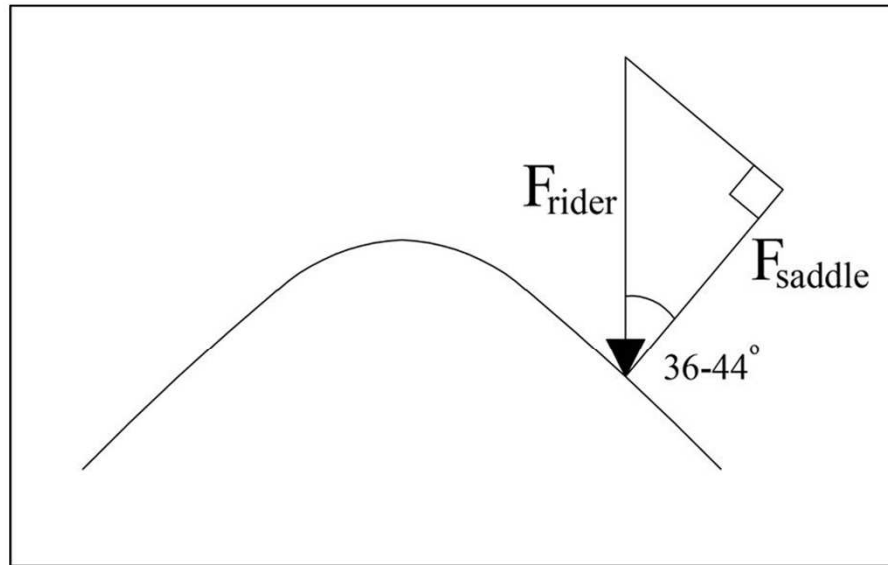
Reduction saddle force: Sitting, rising trot and two-point seat (Peham et al. 2009)



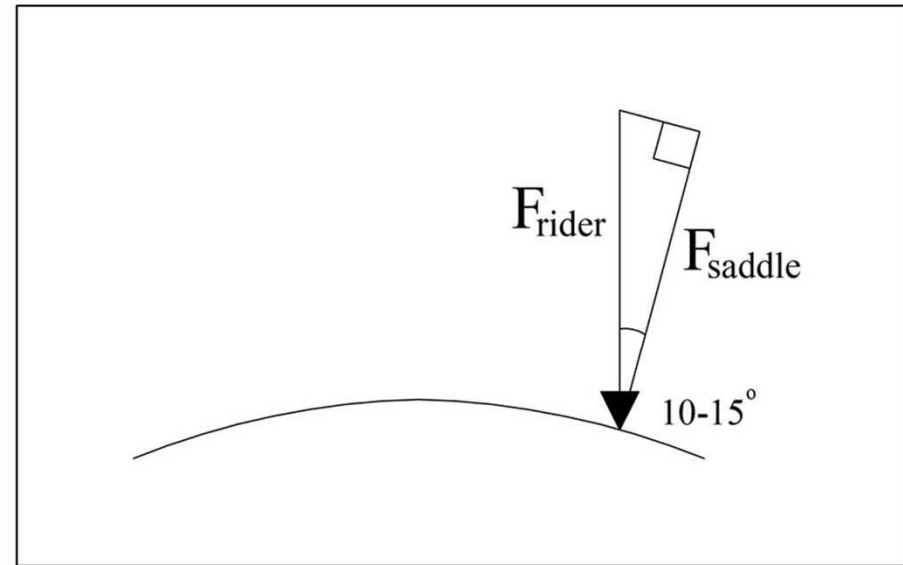
# Saddle force measurements



# Measuring vertical forces of the rider



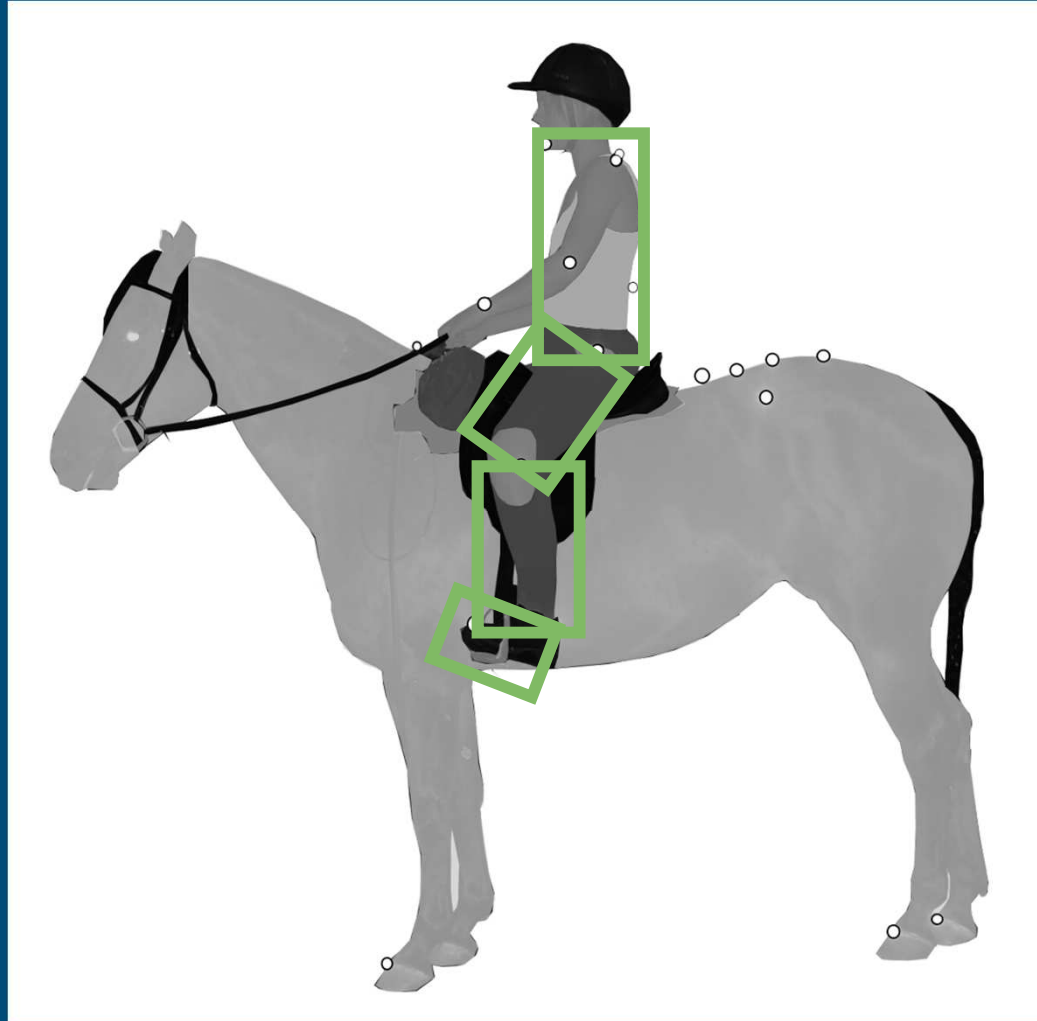
a



b

Problem using saddle force to evaluate vertical force of rider

# Calculating vertical forces from rider's kinematics



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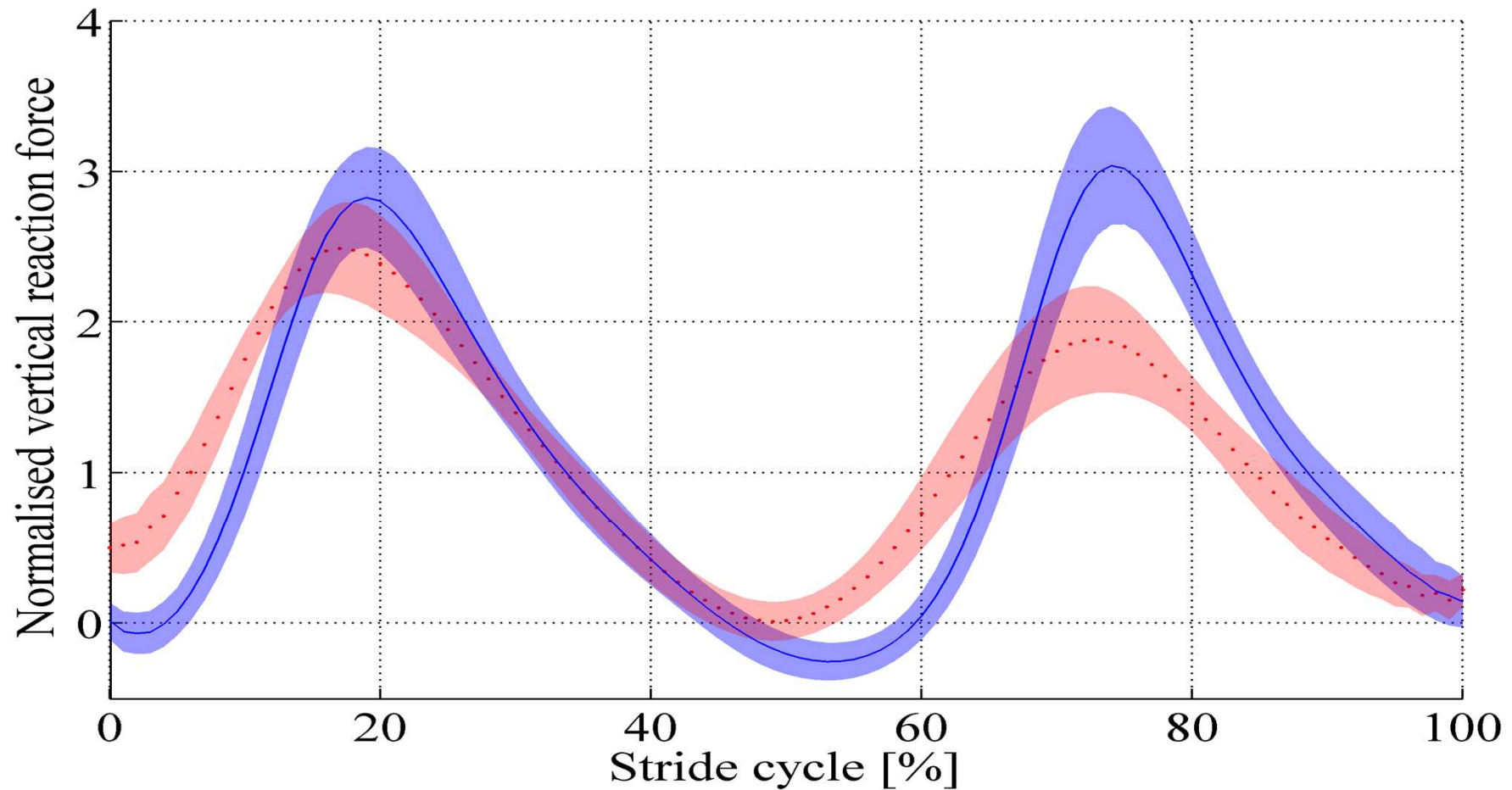
## Calculating vertical forces from rider's kinematics

$$F_{z\_rider} = m_B (\ddot{z}_{MCB} - g)$$

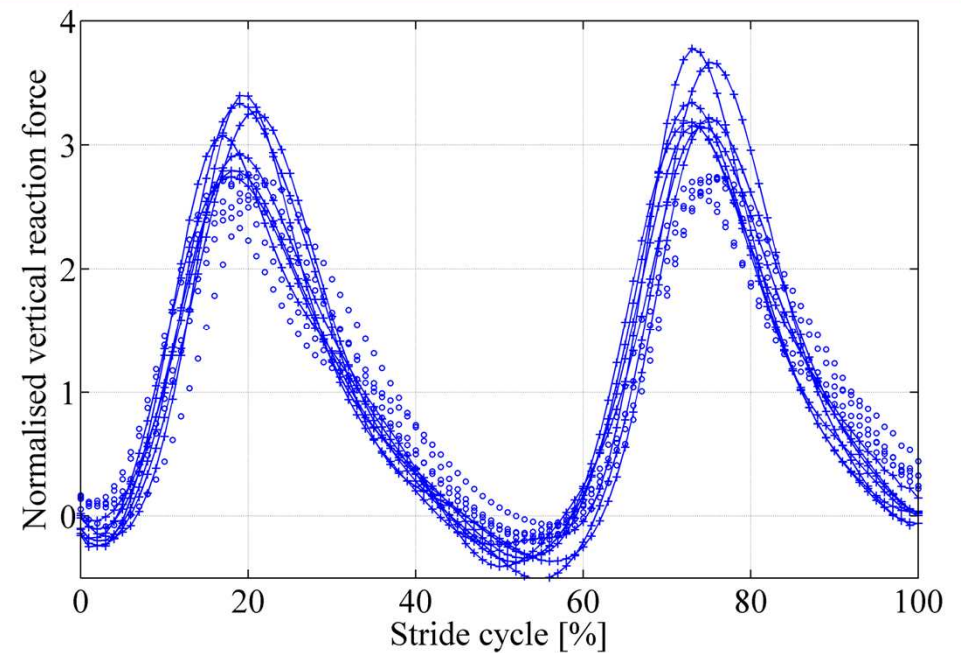
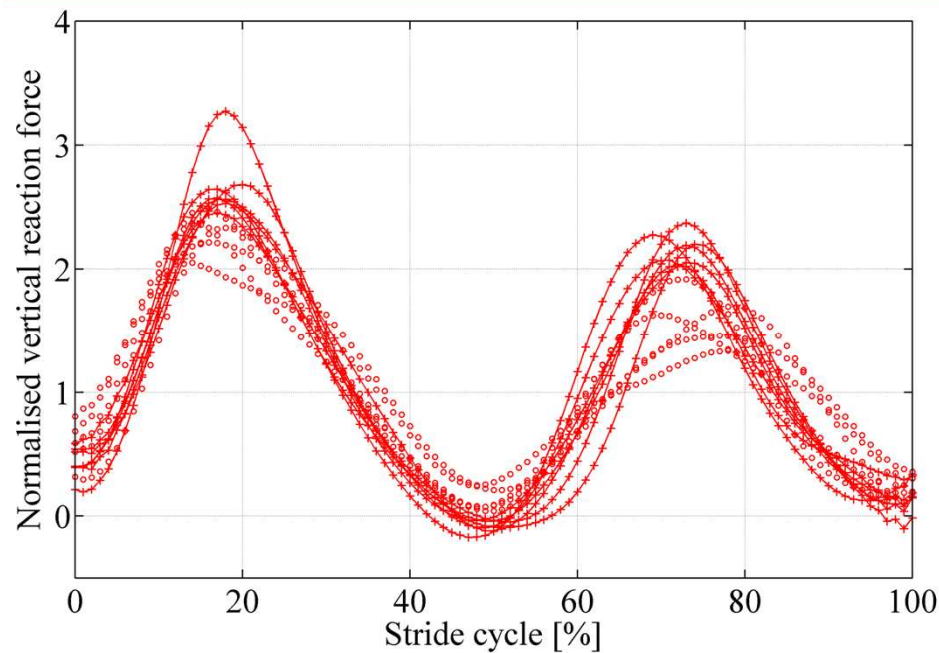
$$F_{z\_rider} = \sum_{i=1}^4 m_i (\ddot{z}_{CM,i} - g)$$



# Sitting trot versus rising trot



# Differences between horses

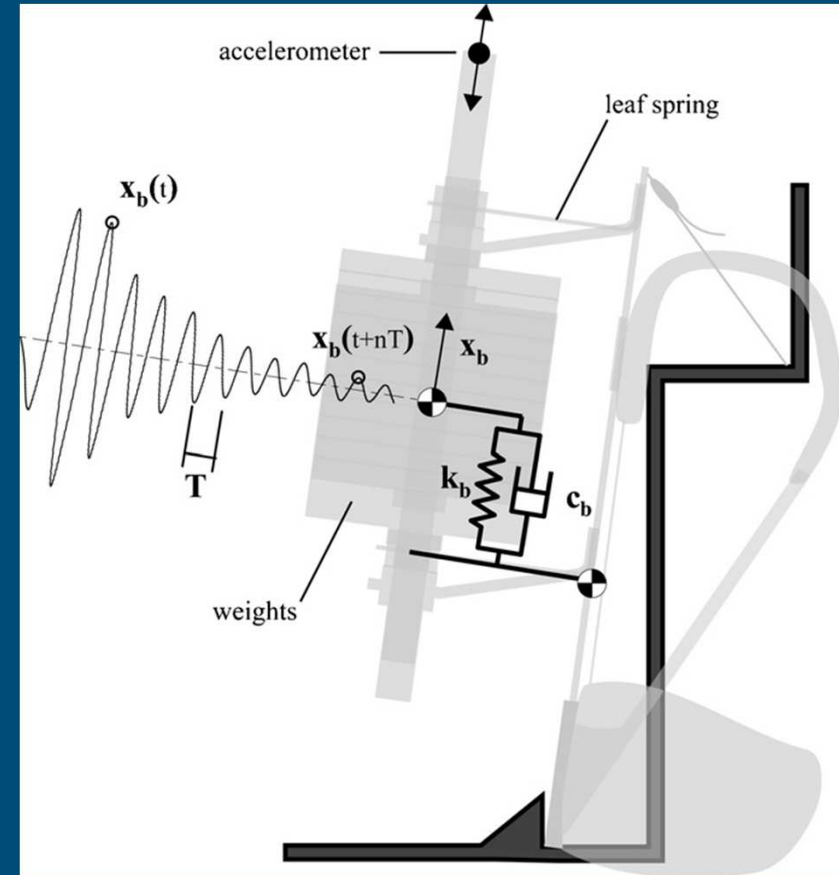
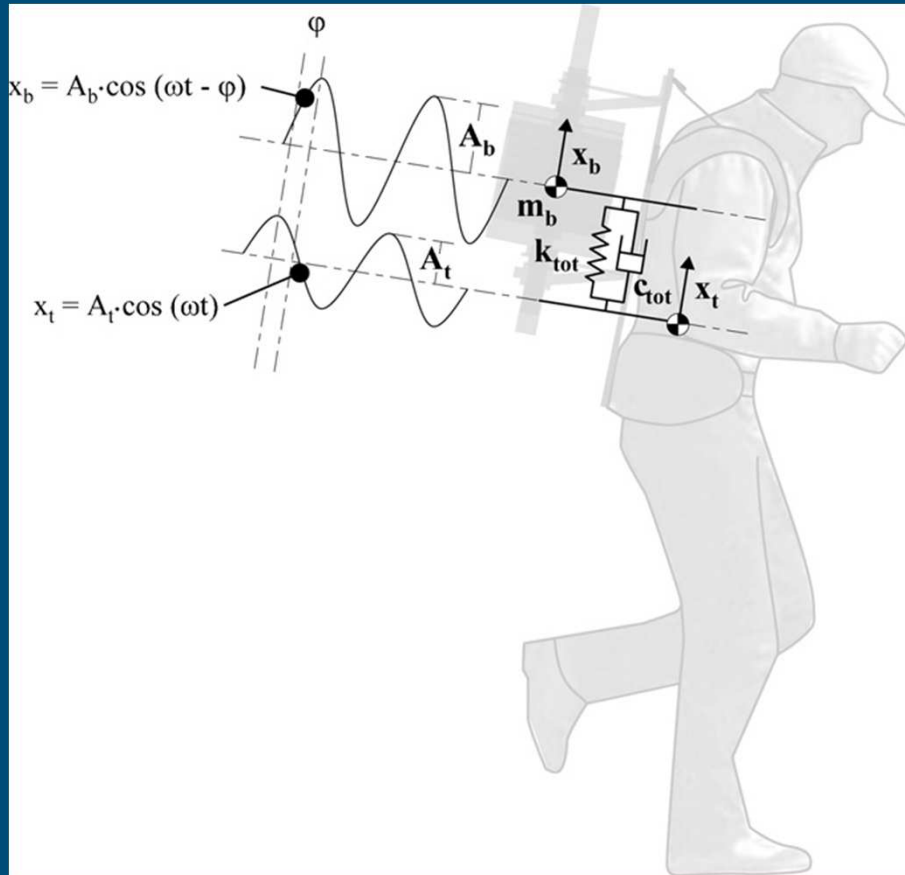




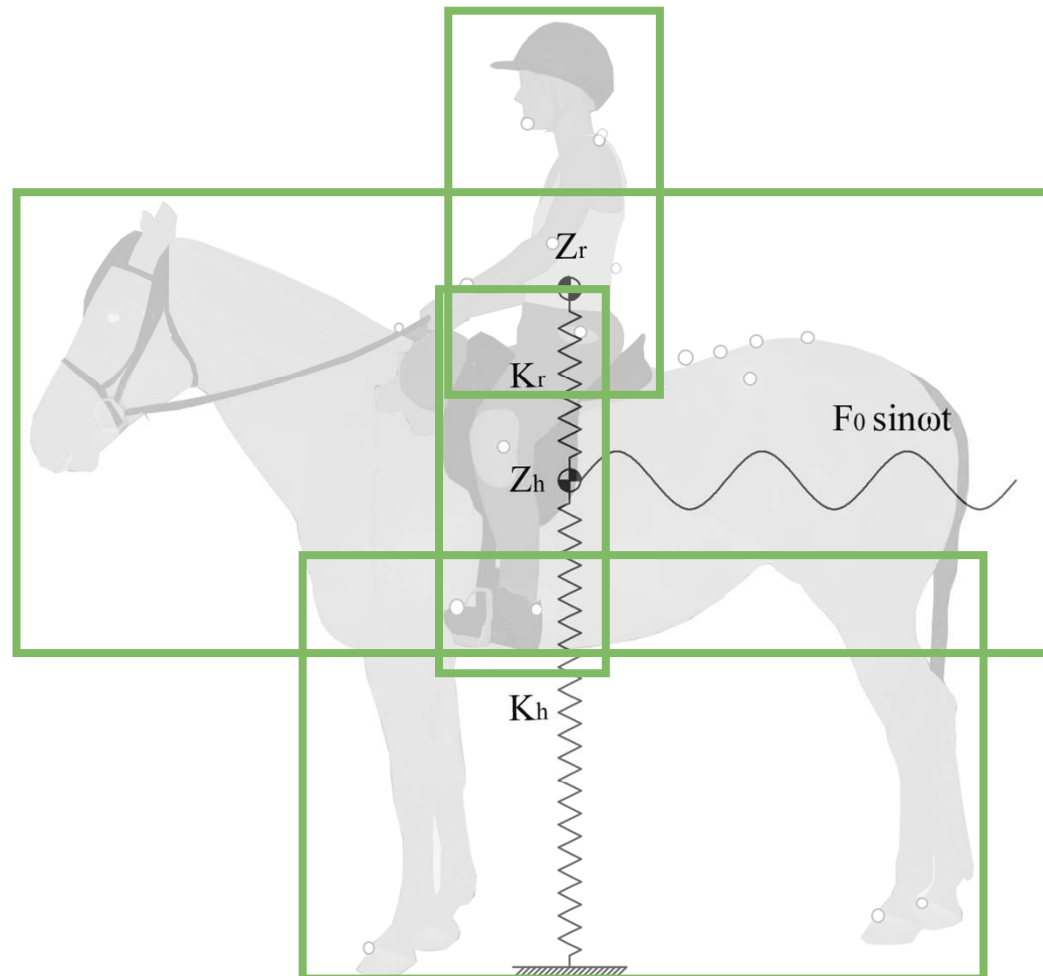
# Understanding horse-rider interaction

- Mechanisms of load carriage – energetics (Taylor et al. 1980; Heglund et al. 1995; Foissac et al. 2009)
- Reduction vertical force of rider
  - Racing horses (Pfau et al. 2009)
  - Sitting and rising trot (de Cocq et al. 2009, 2010; Peham et al. 2009)
- Interaction horse and rider: need for mathematical modelling

# Example modelling human-backpack interaction



# Basic spring-mass model





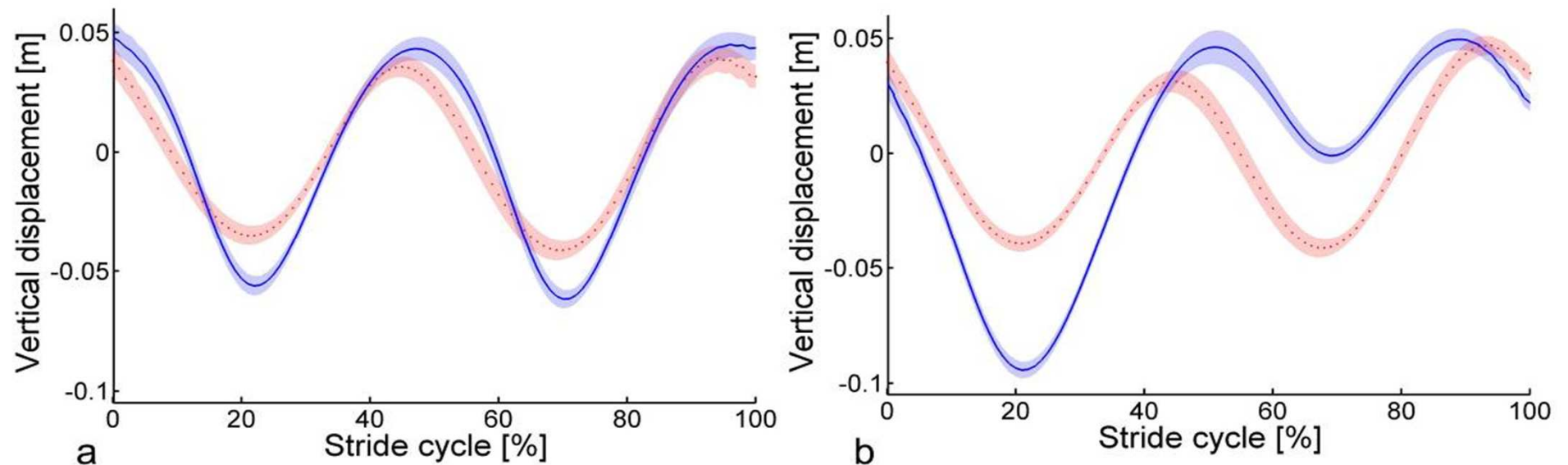
## Input parameters

- Mass horse = 600 [kg]
- Spring constant horse = 75 [kN/m]
- Mass rider = 30-150 [kg]
- Spring constant rider = 0.5-100 [kN/m]
- $F_0 = 3000$  [N]
- Frequency = 2.4 [Hz]

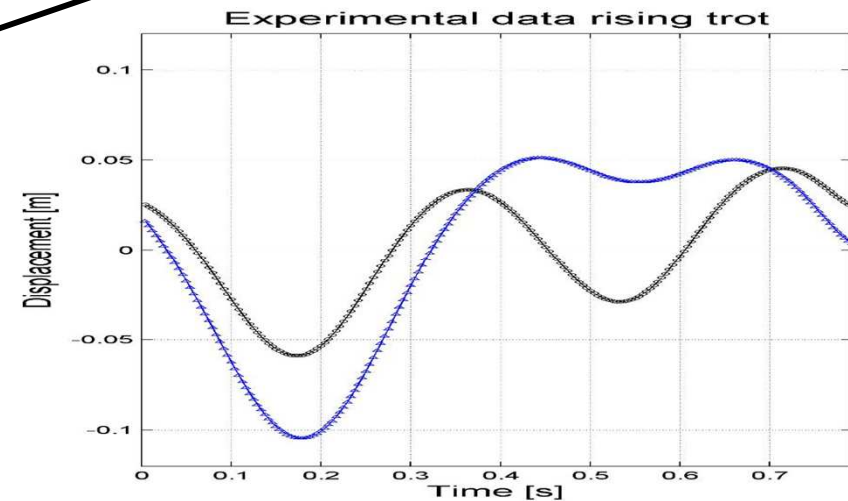
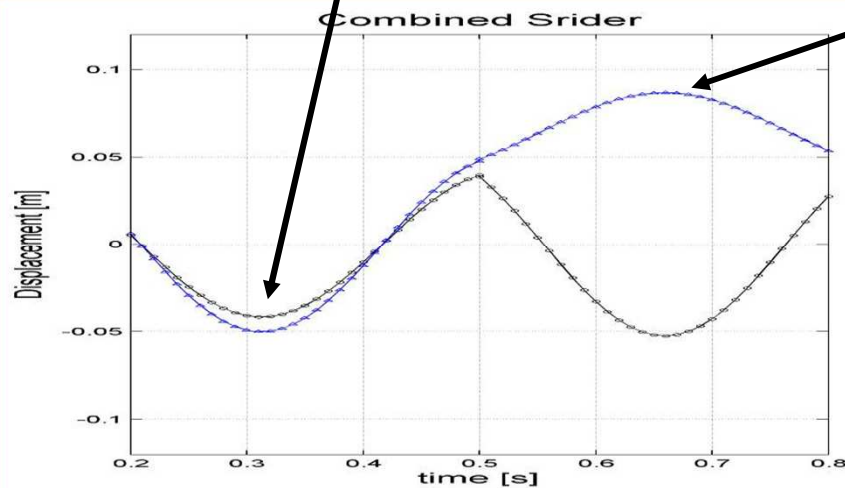
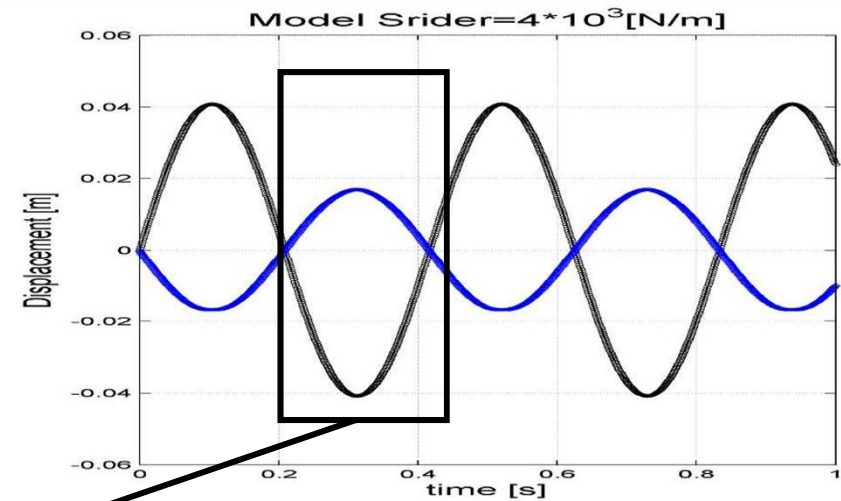
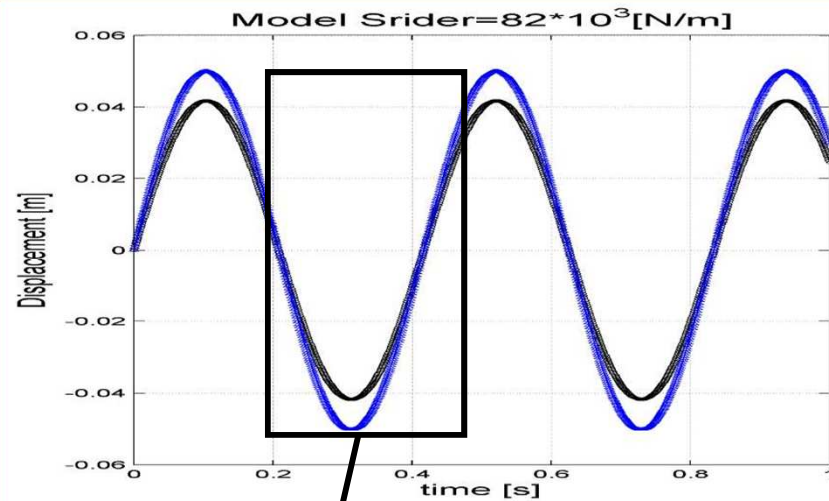
## Output variables

- Displacement horse [m]
- Displacement rider [m]  
→ Both experimental movement data
- Force horse [N]
- Force rider [N]  
→ Ground reaction forces, forces underneath the saddle, forces on the stirrups.

# Experimental movement data



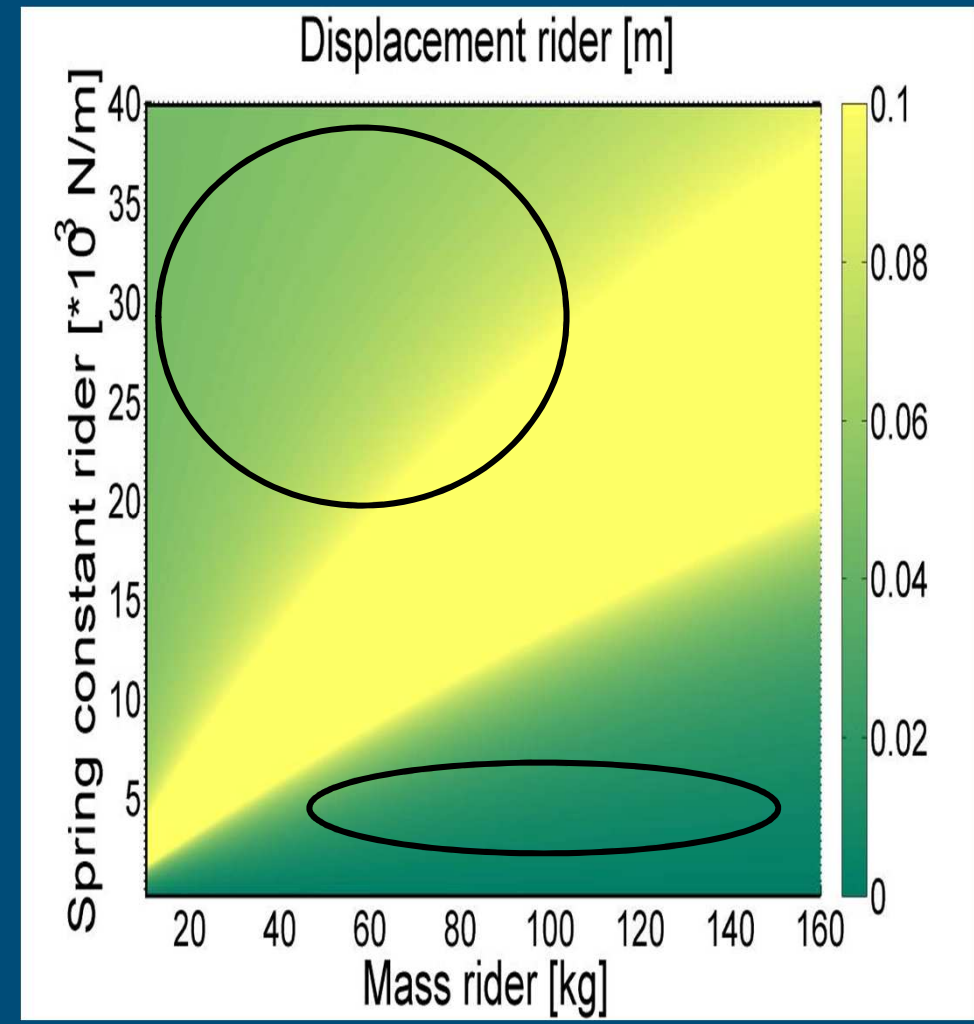
# Varying spring rider $\rightarrow$ rising trot?



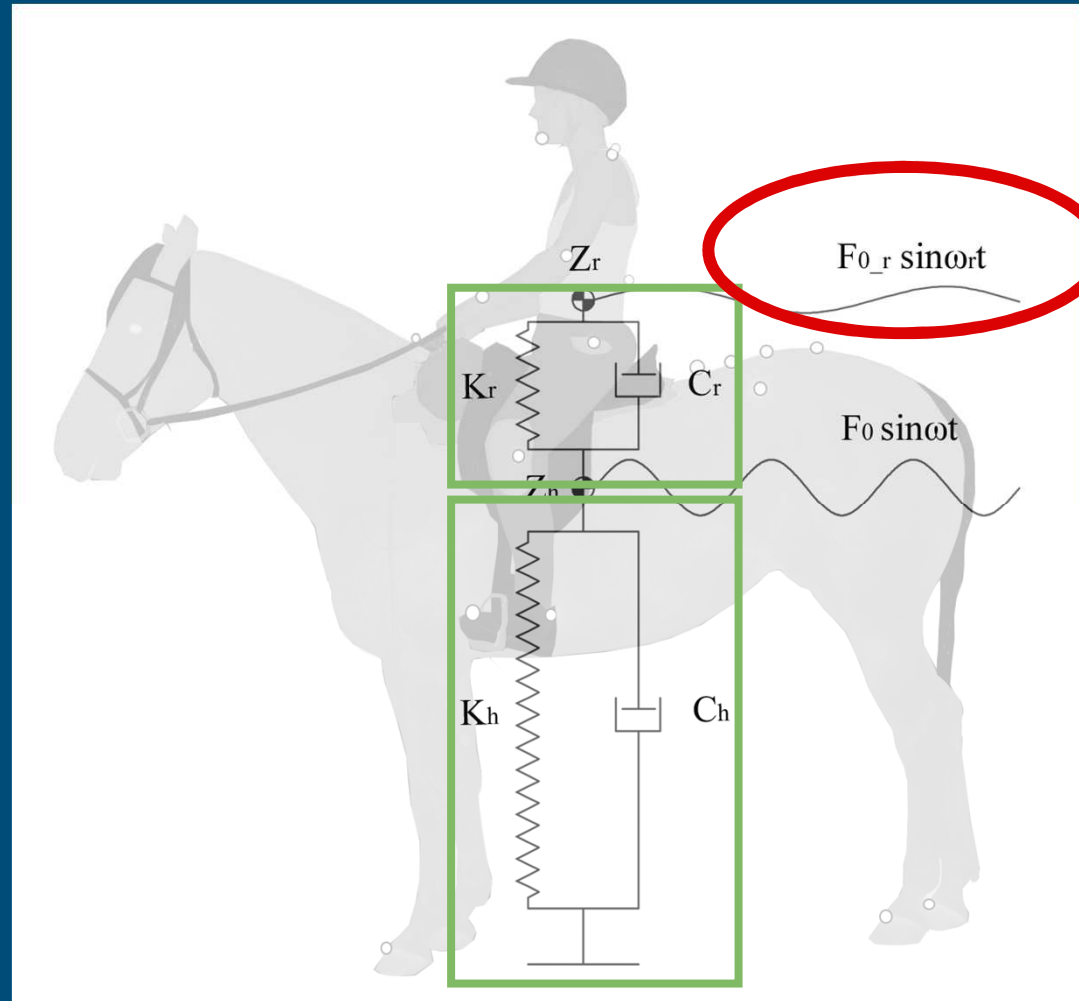


## Displacement rider: mass and spring constant rider

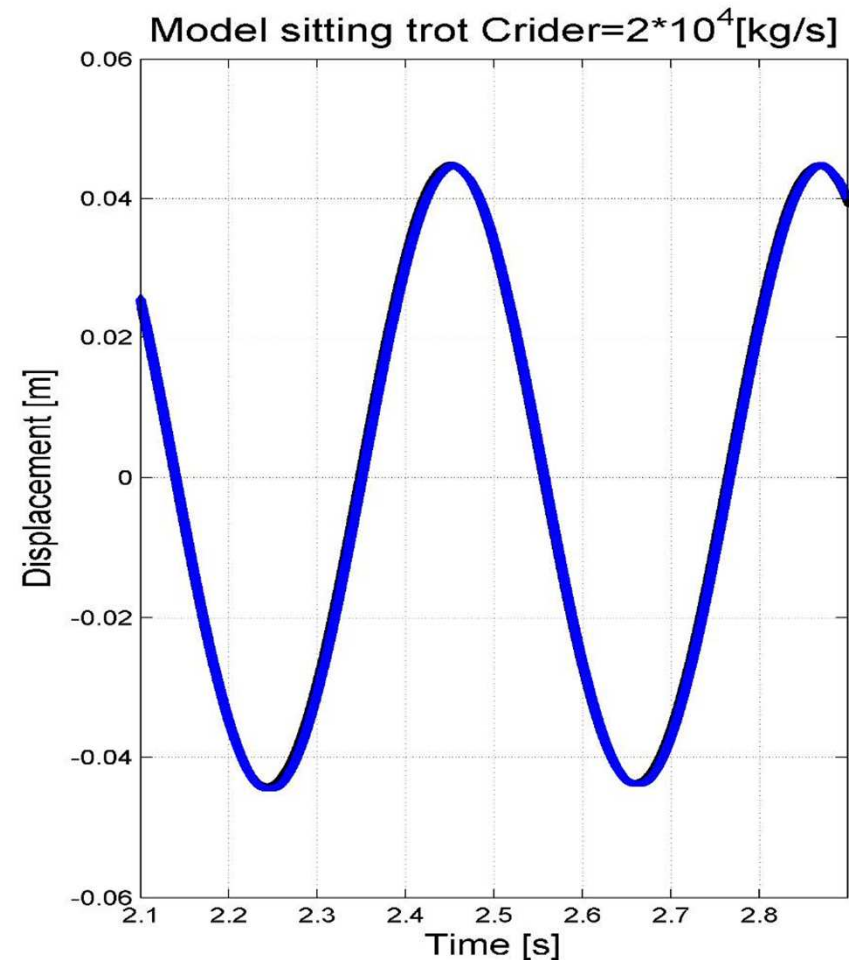
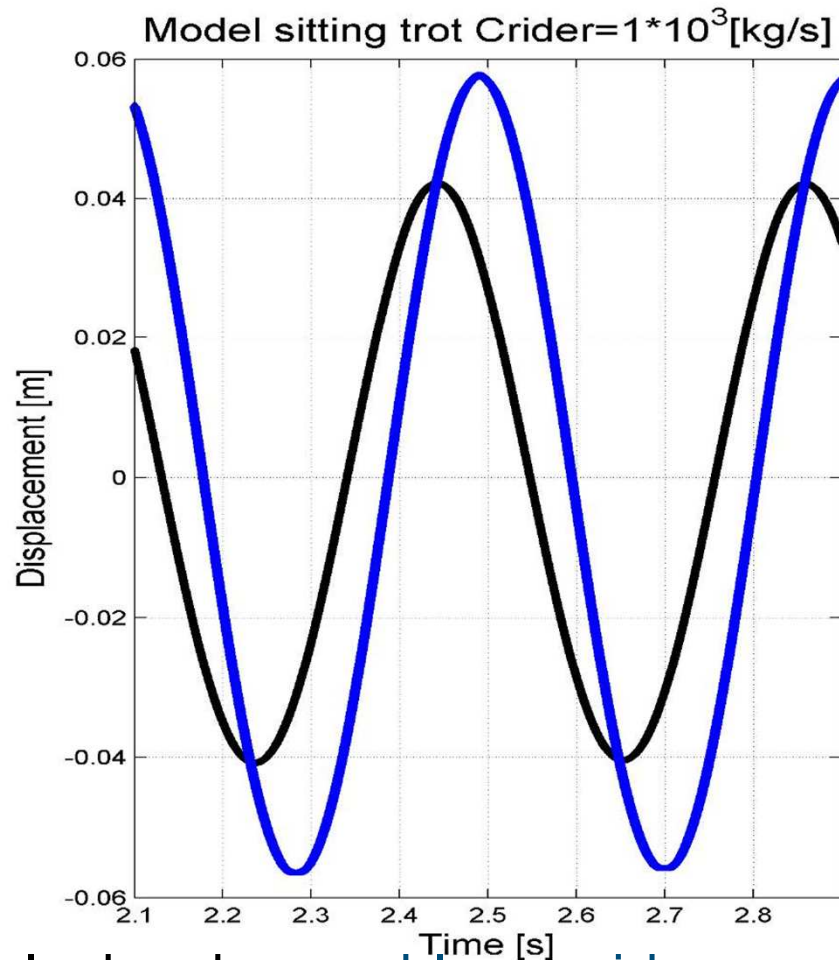
- Sitting trot
  - High spring constant rider
  - Increase of mass rider → higher spring constant rider
- Rising trot
  - Specific combination spring constants rider



# Extended spring-mass model



# Effect damping: riding levels (Lagarde et al. 2005)



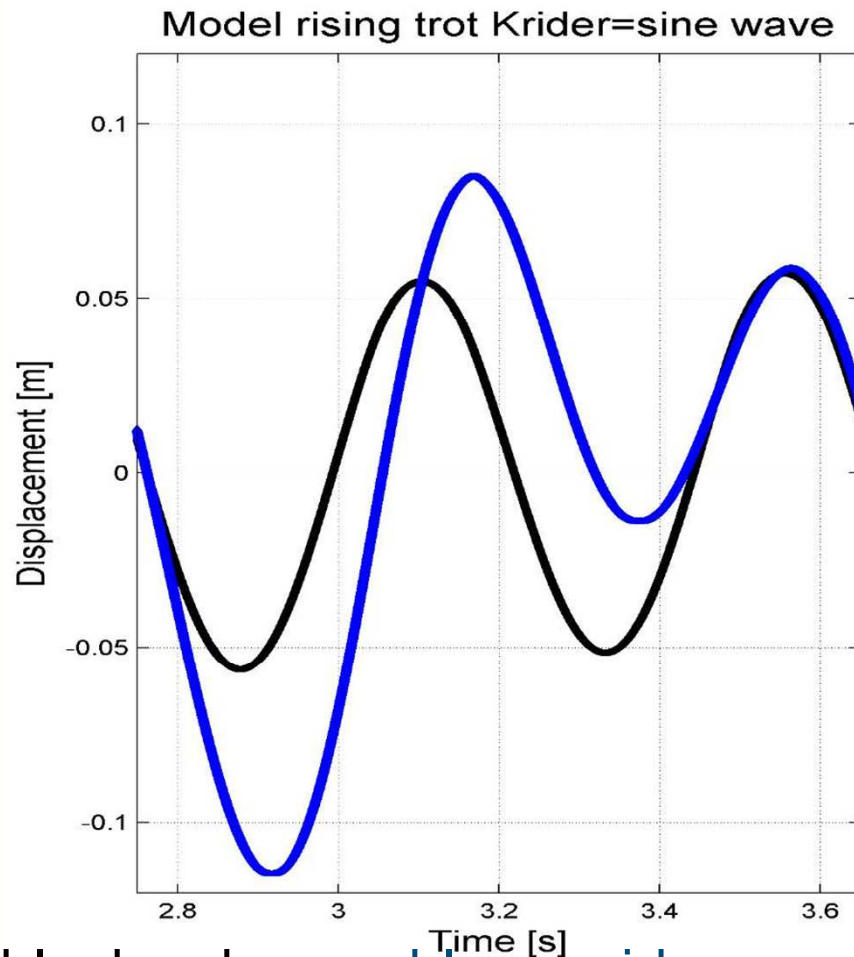
black = horse; blue = rider



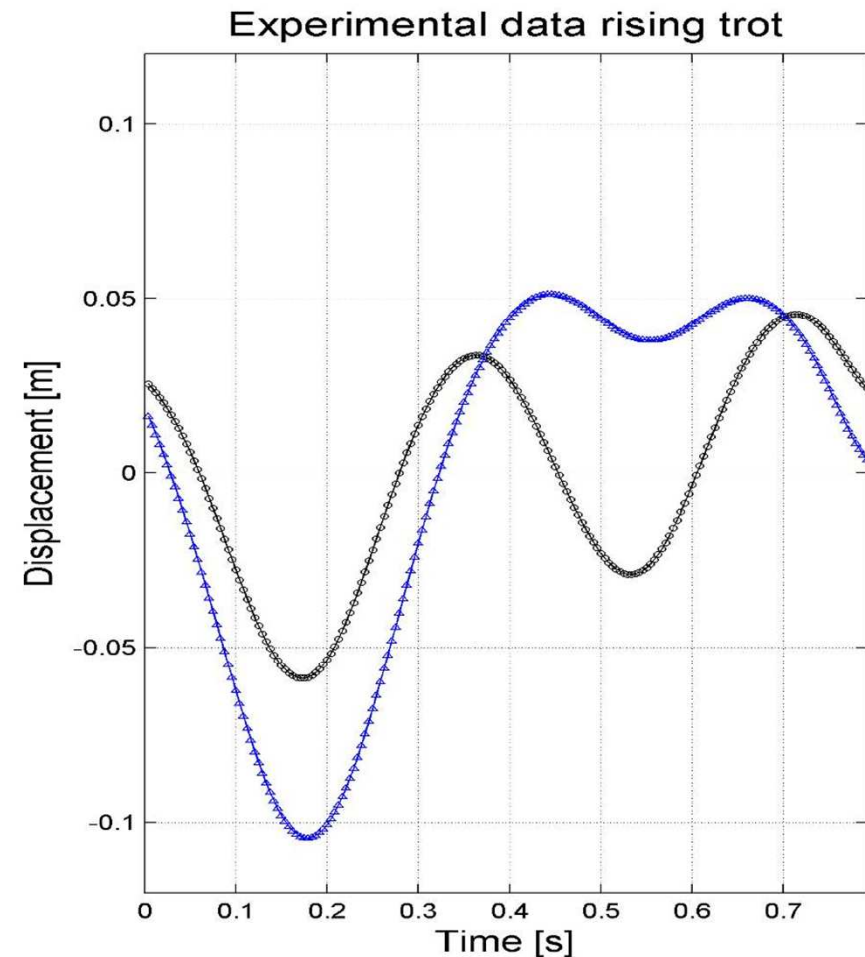
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# Rising trot: varying $K_{\text{rider}}$ ( $K_{\text{rider}} = K_{\text{base}} + K_{\text{amp}} \sin(\varphi + \omega_r t)$ )

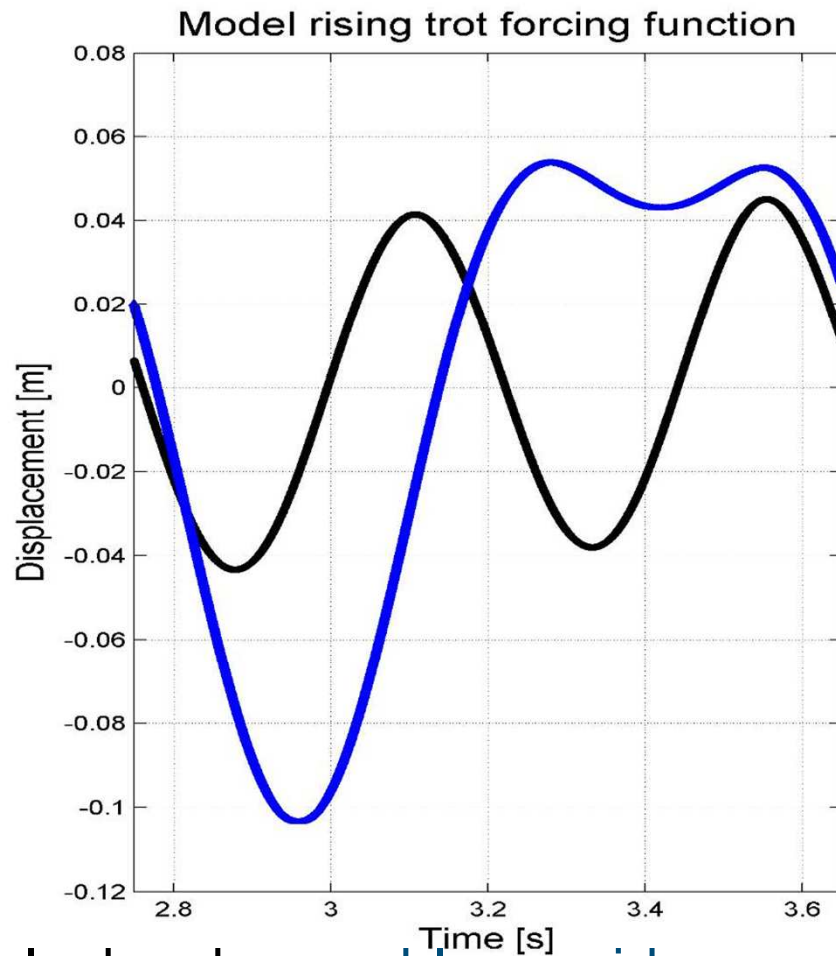


black = horse; blue = rider

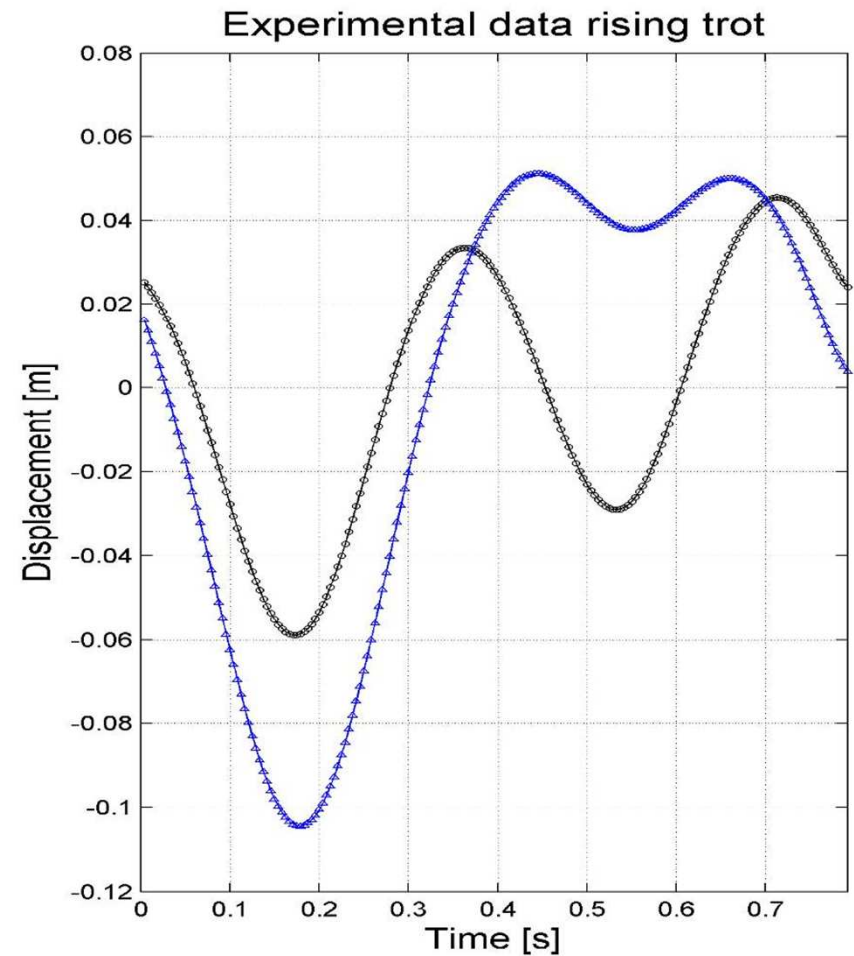


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# Rising trot: forcing function



black = horse; blue = rider



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# Future of biomechanics of horse-rider interaction

- Interaction between experimental and modelling approach
- Interaction between biomechanics, sport physiology, ethology and genetics
- Interaction between sports, equine industry and research





**Thank you for your  
attention!**

**A bit itchy in the back,  
don't you think?**