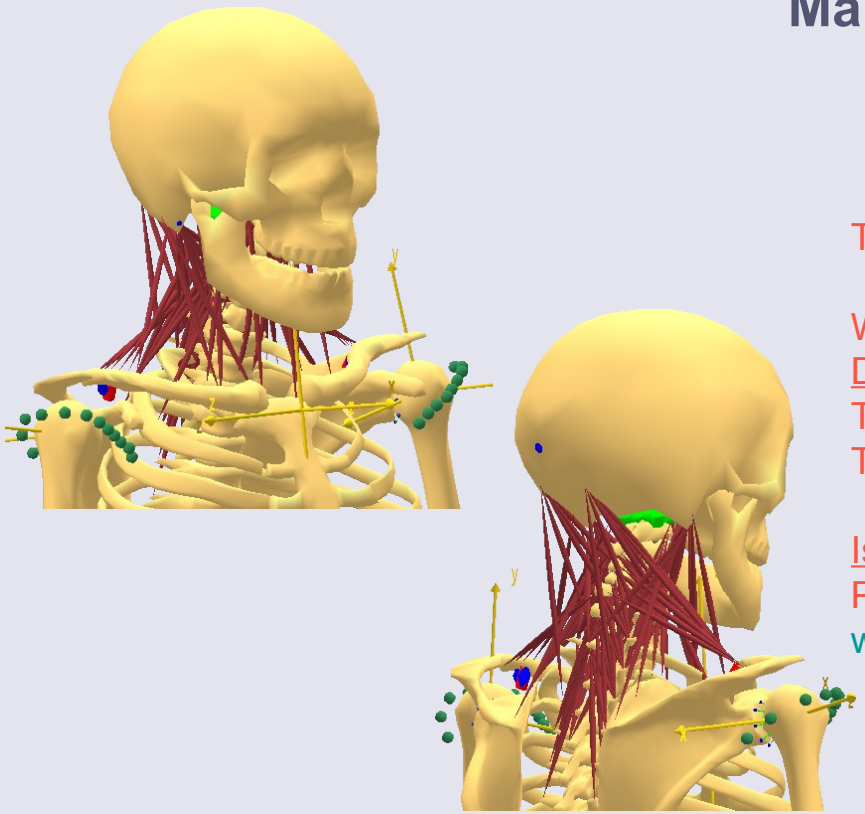
A detailed rigid-body cervical spine model based on inverse dynamics

Mark de Zee



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AALBORG UNIVERSITY
Department of Mechanical Engineering

SMI CENTER FOR SENSORY-MOTOR INTERACTION

ANYBODY RESEARCH PROJECT

Presenters

Mark de Zee
(Presenter)

Arne Kiis
(Host)

Søren T. Christensen
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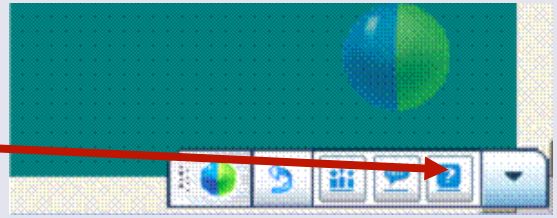

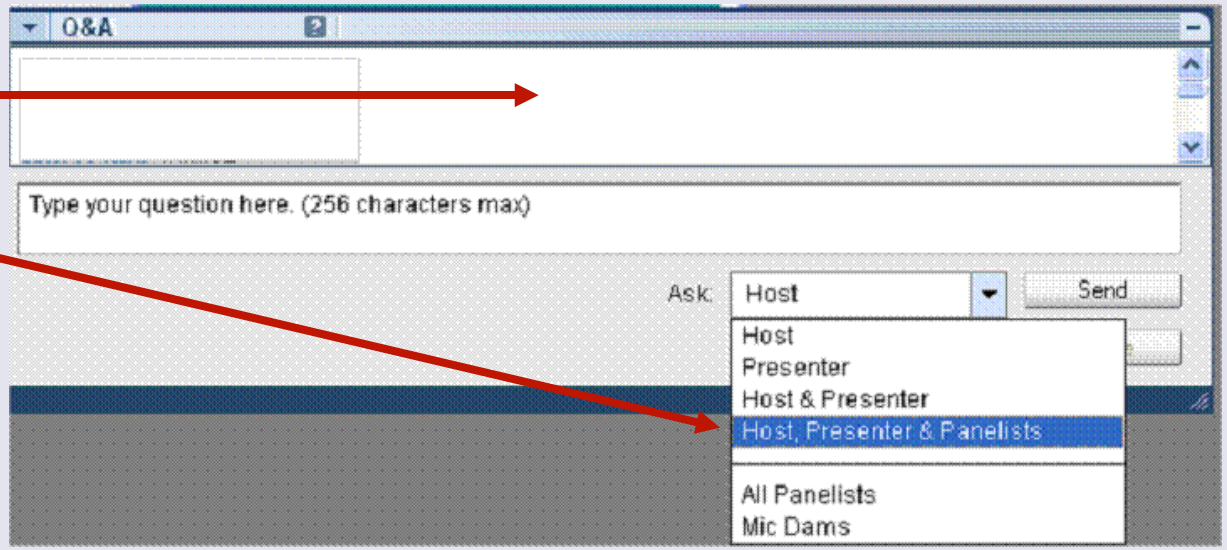

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- From Department of Mechanical Engineering:
  - John Rasmussen

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Cervical Spine

- Dynamic structure which acts to support the head on the trunk, orient the head in space and transmit forces arising from the trunk that will influence the position of the head

- Complex biomechanical system composed of numerous degrees of freedom of movement about each of its joints and at least 20 pairs of muscles, many of which are capable of performing similar functions

- This system is highly redundant - specific forces may be produced by several combinations of muscle actions

Relevance

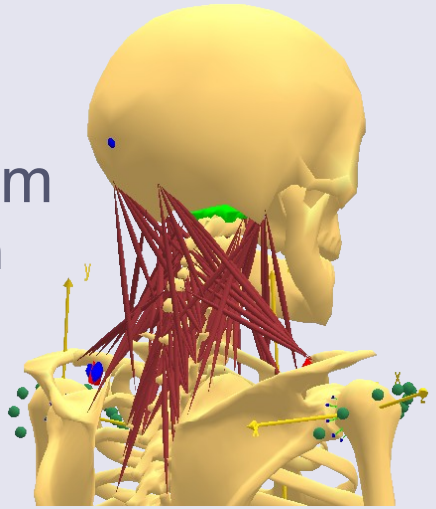
- Neck pain is a significant problem in society and its frequency is beginning to match the proportions of back pain, probably reflecting our increasingly sedentary lifestyles.
- Changes in motor control of the cervical spine have been documented in this population
- A prerequisite for understanding the development of discomfort and neck pain is quantification of the loading of the muscles and the structures of the cervical spine for different working postures and movements

Our goal

- To develop a general detailed cervical spine model which:
  - can predict muscle and reaction forces in the cervical spine for a given movement or posture
  - will facilitate sharing of the model
  - will give the opportunity to scrutinize and improve the model by other groups

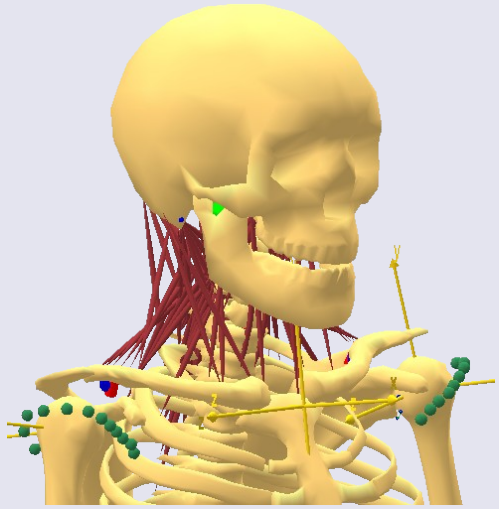
The cervical spine model

- Built in the AnyBody Modeling System
  - Based on inverse dynamics and optimization principles
  - Built-in model definition language: AnyScript



- Data based on a neck model described by Marike van der Horst

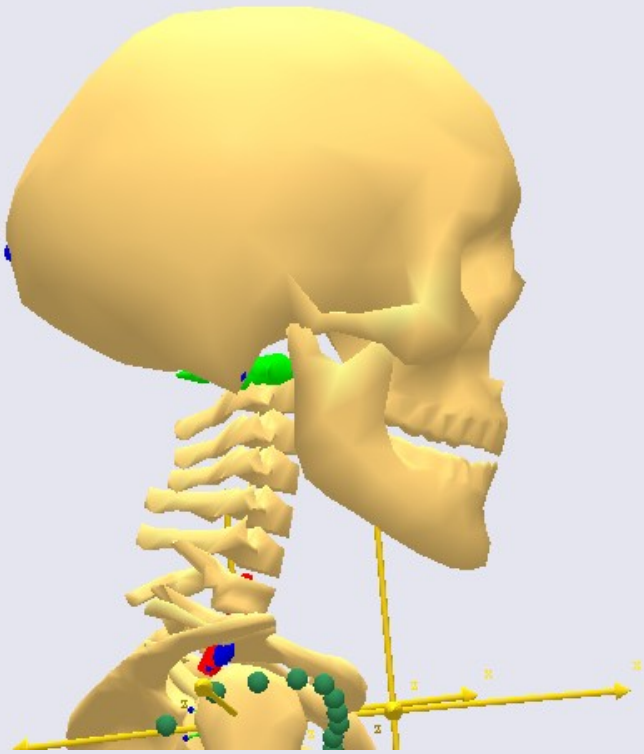
  http://alexandria.tue.nl/extra2/200211336.pdf



Segments and joints

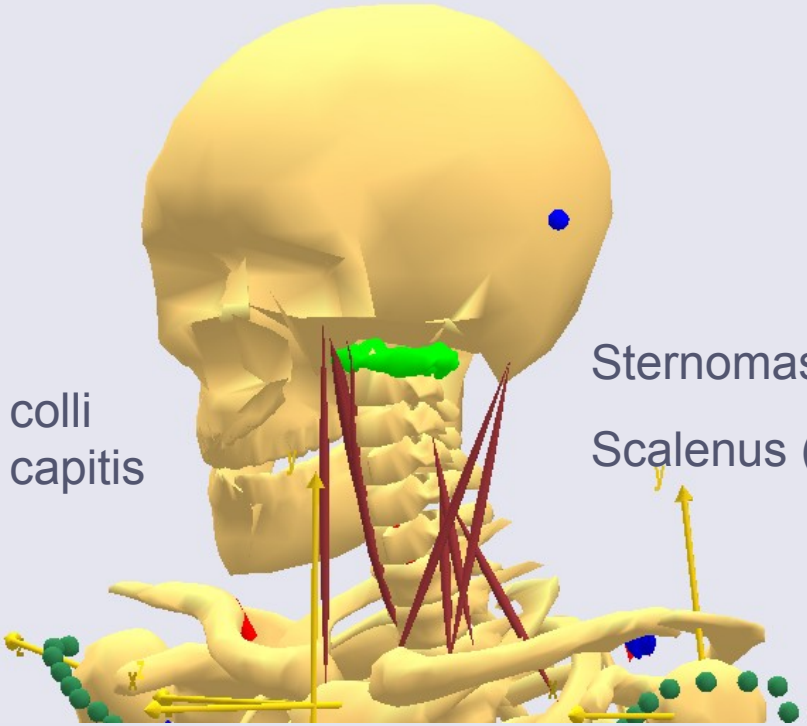
- 9 rigid segments
  - Head
  - 7 vertebrae
  - Thoracic part

- Joints between vertebrae
  - 3 dof spherical joint from T1 to C2
  - 1 dof universal joint from C2 to head
  - Centre of rotation based on Amevo et al. (1991)



Muscles

- 136 muscle fascicles



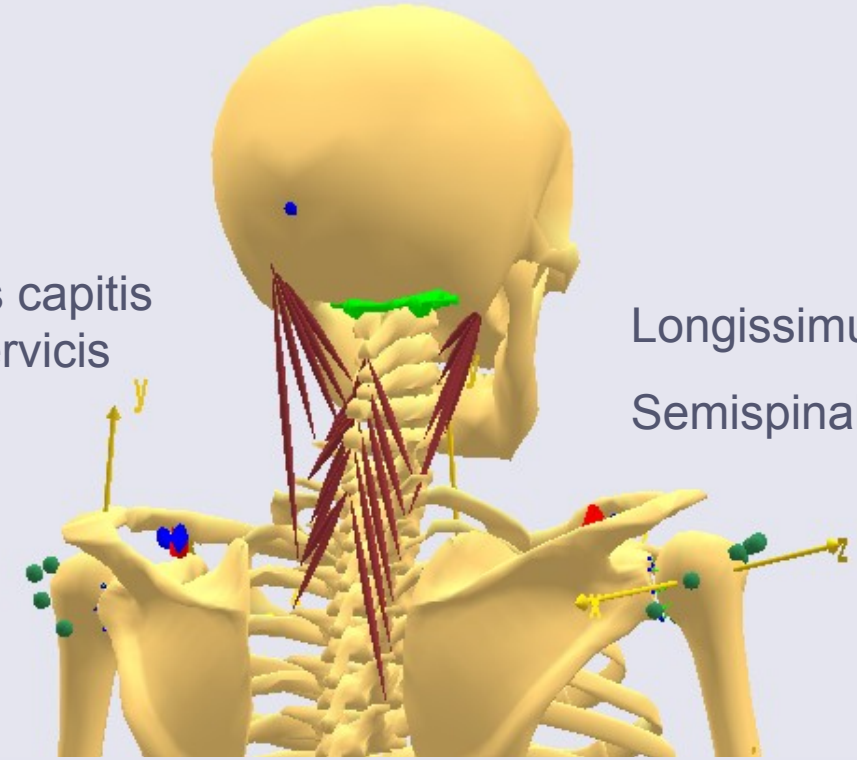
Longus colli
Longus capitis
Hyoid

Sternomastoid

Scalenus (anterior, medius, posterior)

Muscles

- 136 muscle fascicles



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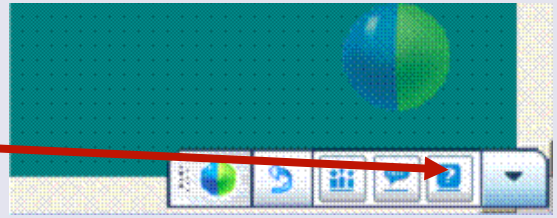

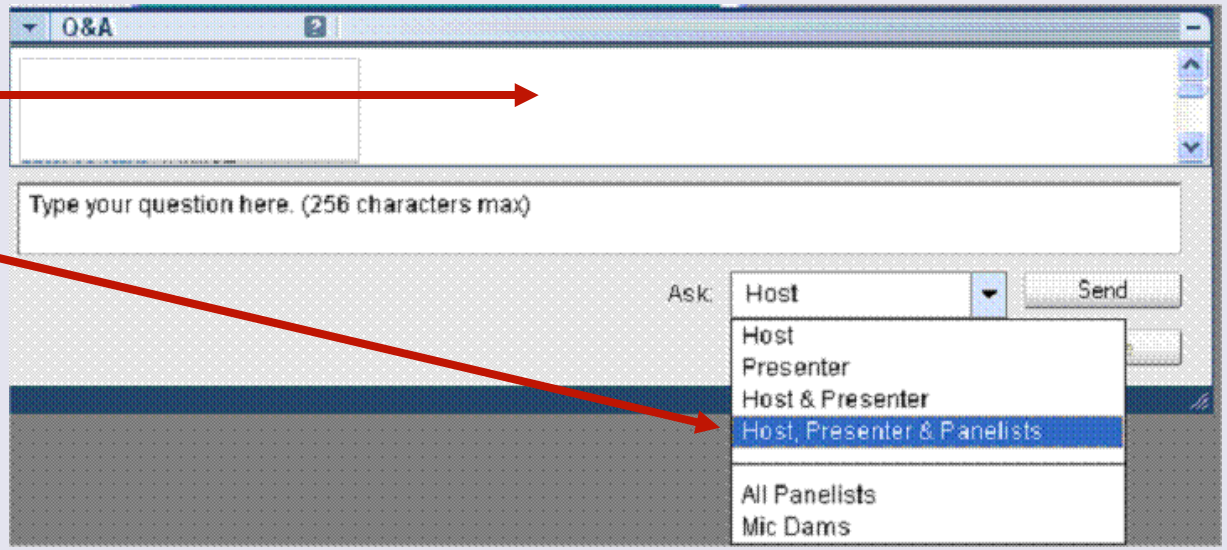

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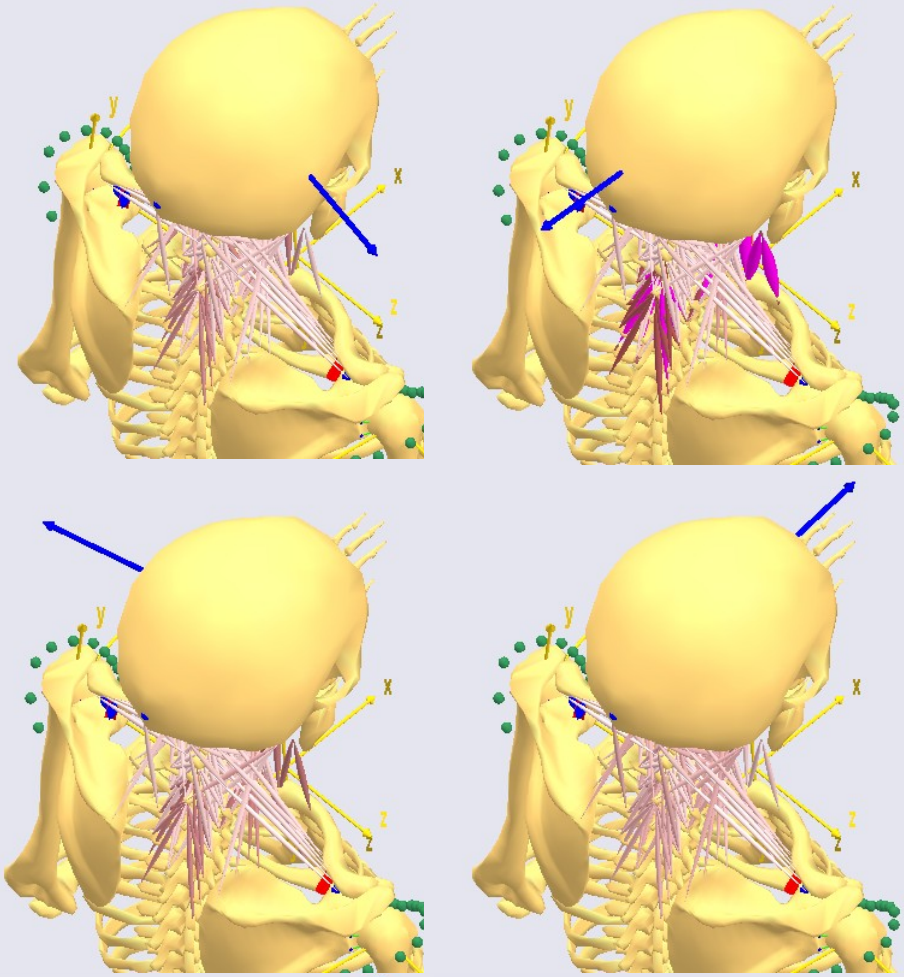
Validation

- Always a big challenge, especially with so many parameters
- As a first approach, we compared the maximal force generation capacity of the cervical spine model in the transverse plane with normative data

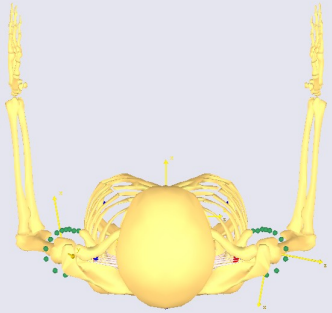
Input to the model

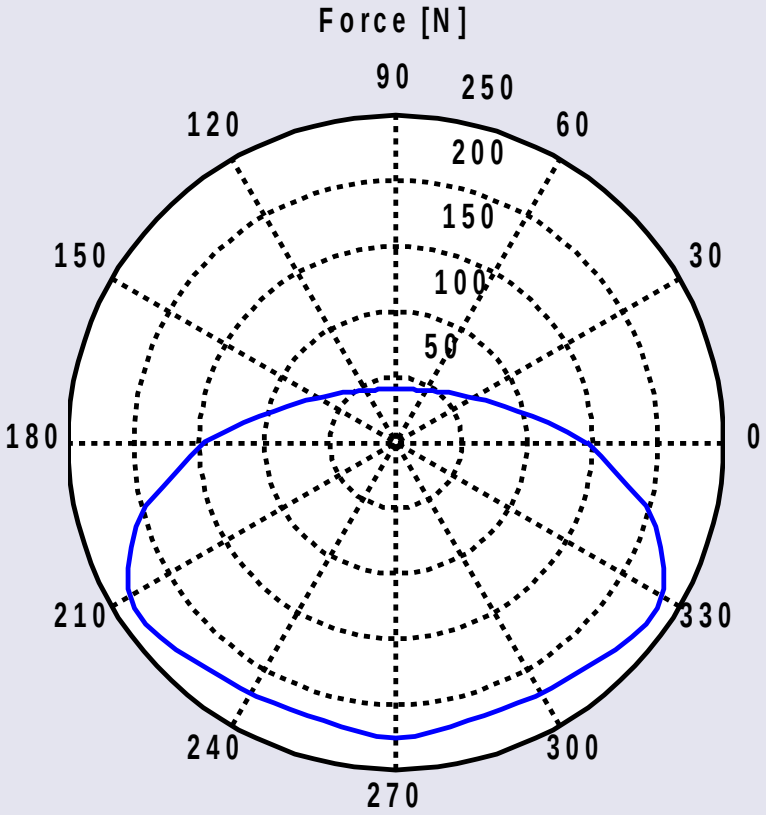


A horizontal force vector was imposed on the head rotating 360 degrees about the vertical axis

Validation: force generation capacity

Flexion
(41 N)





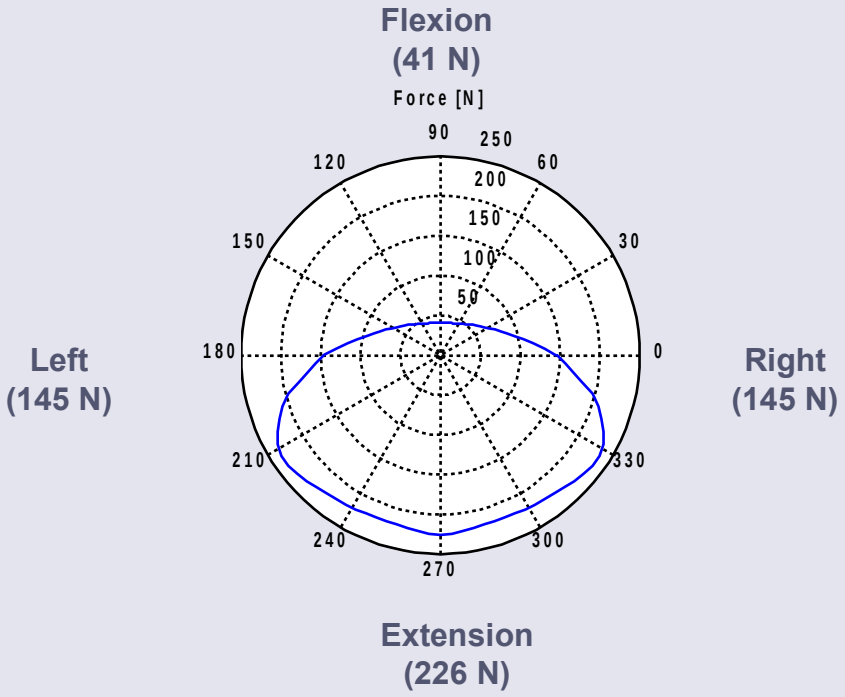
Left
(145 N)

Right
(145 N)

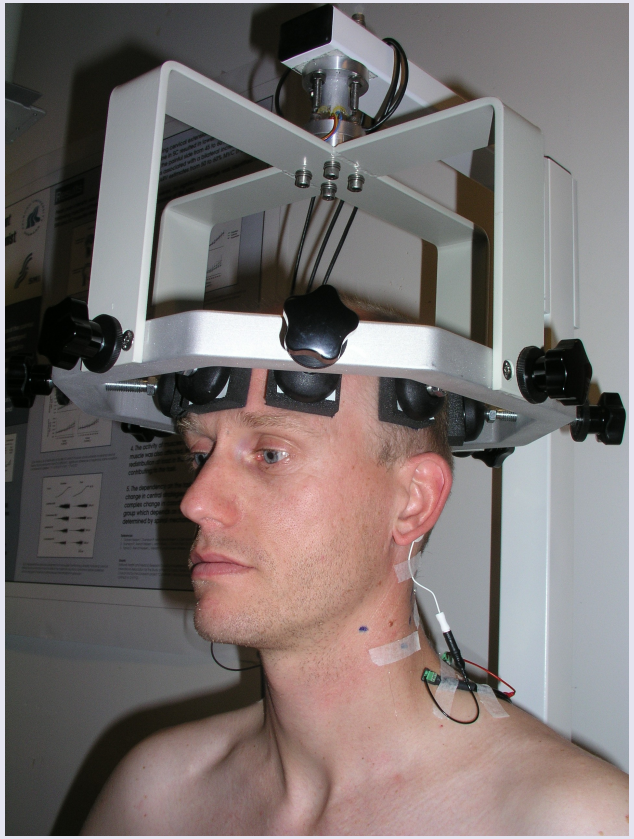
Extension
(226 N)

Discussion: force generation capacity

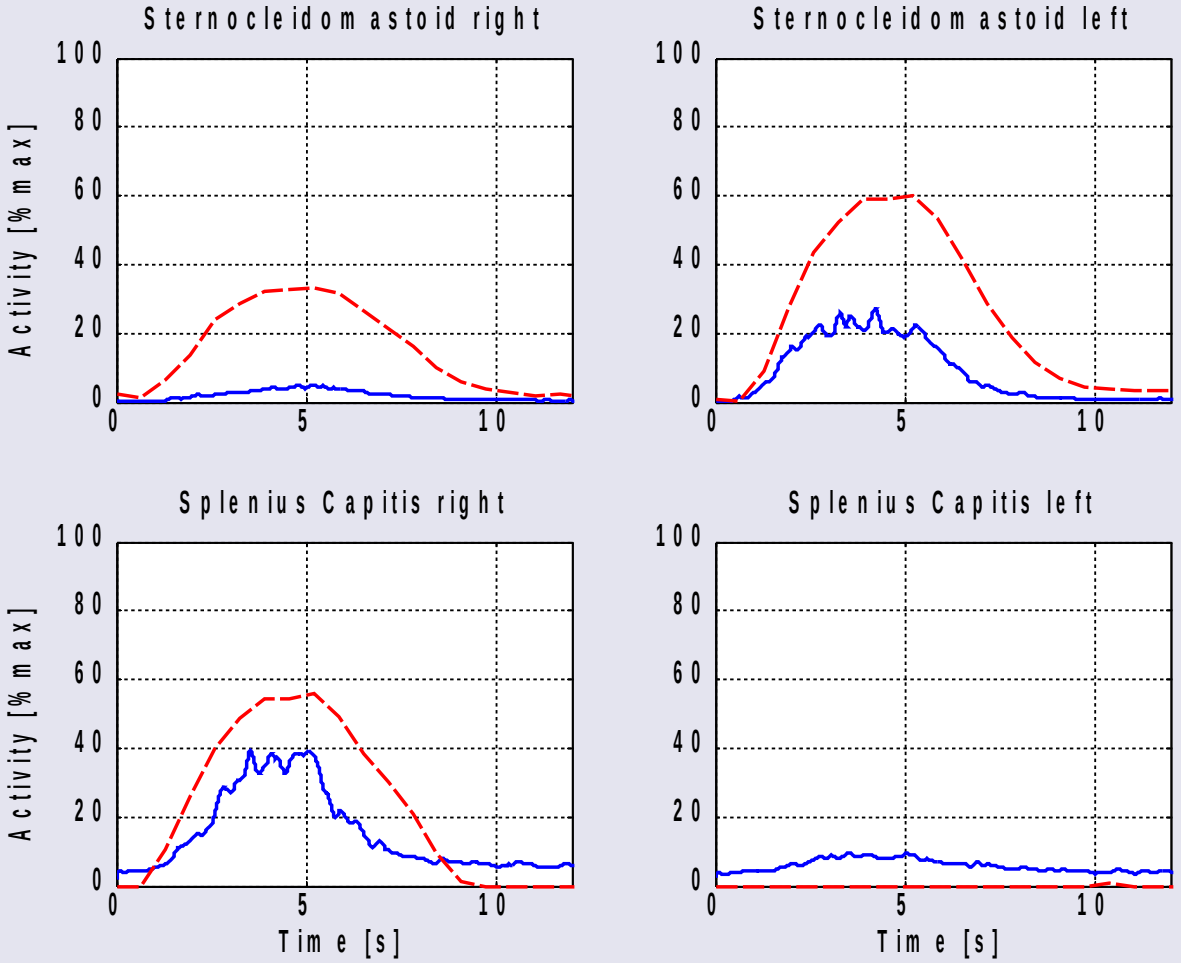
- Maximal extension and lateral flexion forces are consistent with values reported in the literature
- Maximal flexion force is within the range of normative data 40 – 150 N



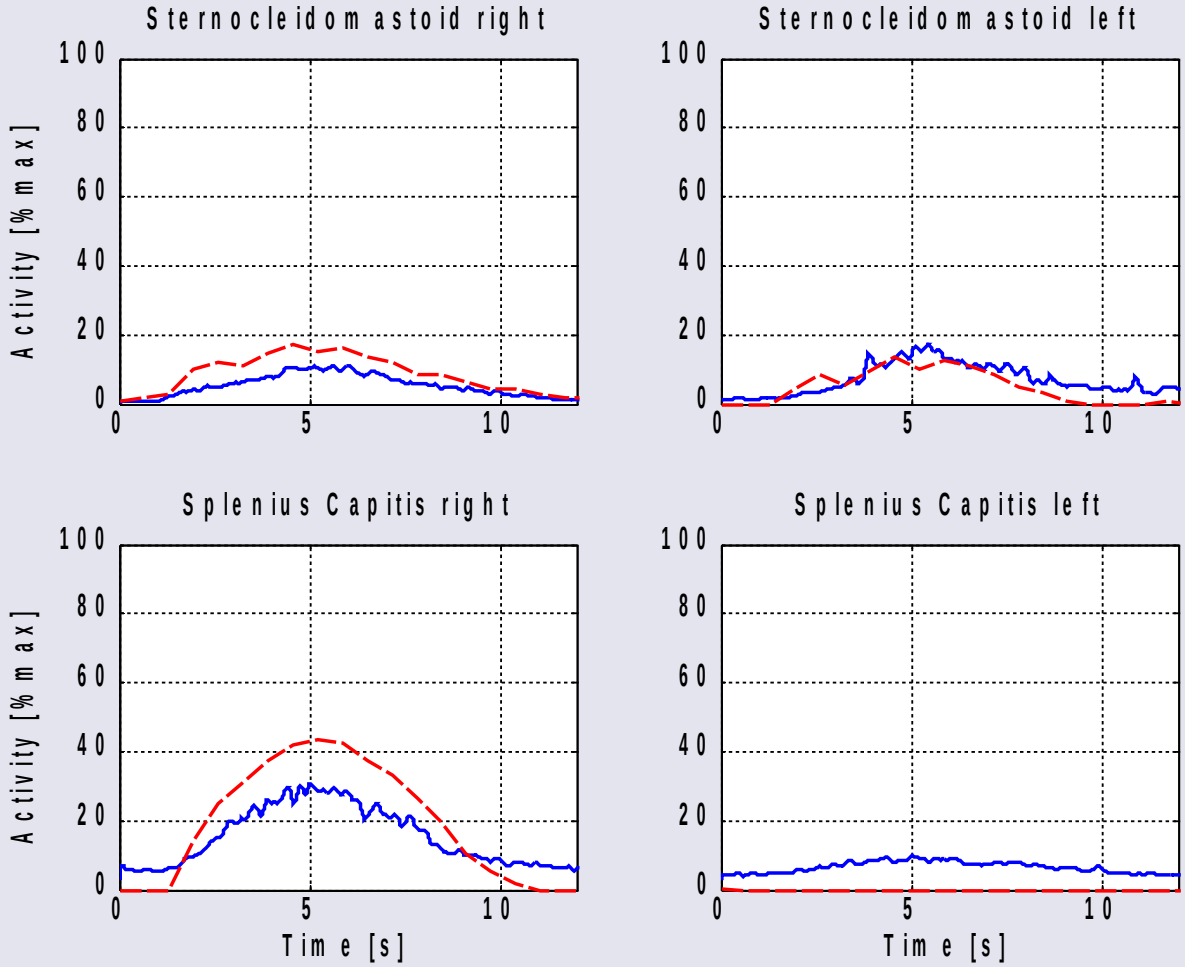
Validation: pilot experiment



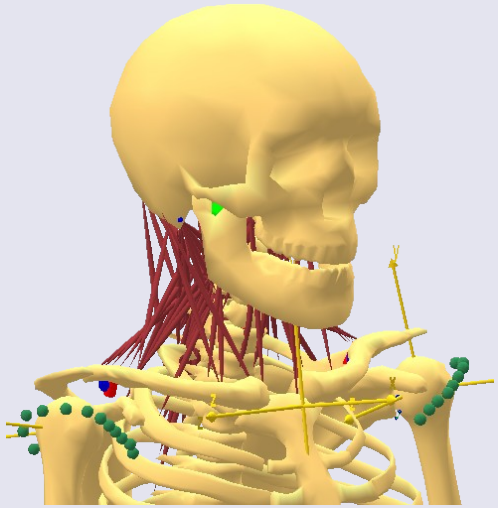
Preliminary results: isometric rotation

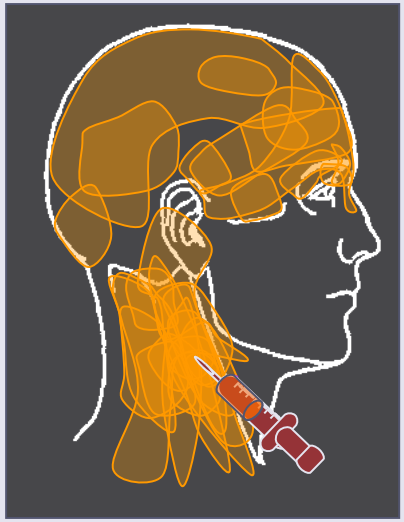


Preliminary results: isometric lateral flexion



Application: Prediction of neuromuscular adaptation of experimentally induced neck pain using a musculoskeletal model





Neck pain

- Neck pain is a significant problem in society and its frequency is beginning to match the proportions of back pain, probably reflecting our increasingly sedentary lifestyles.

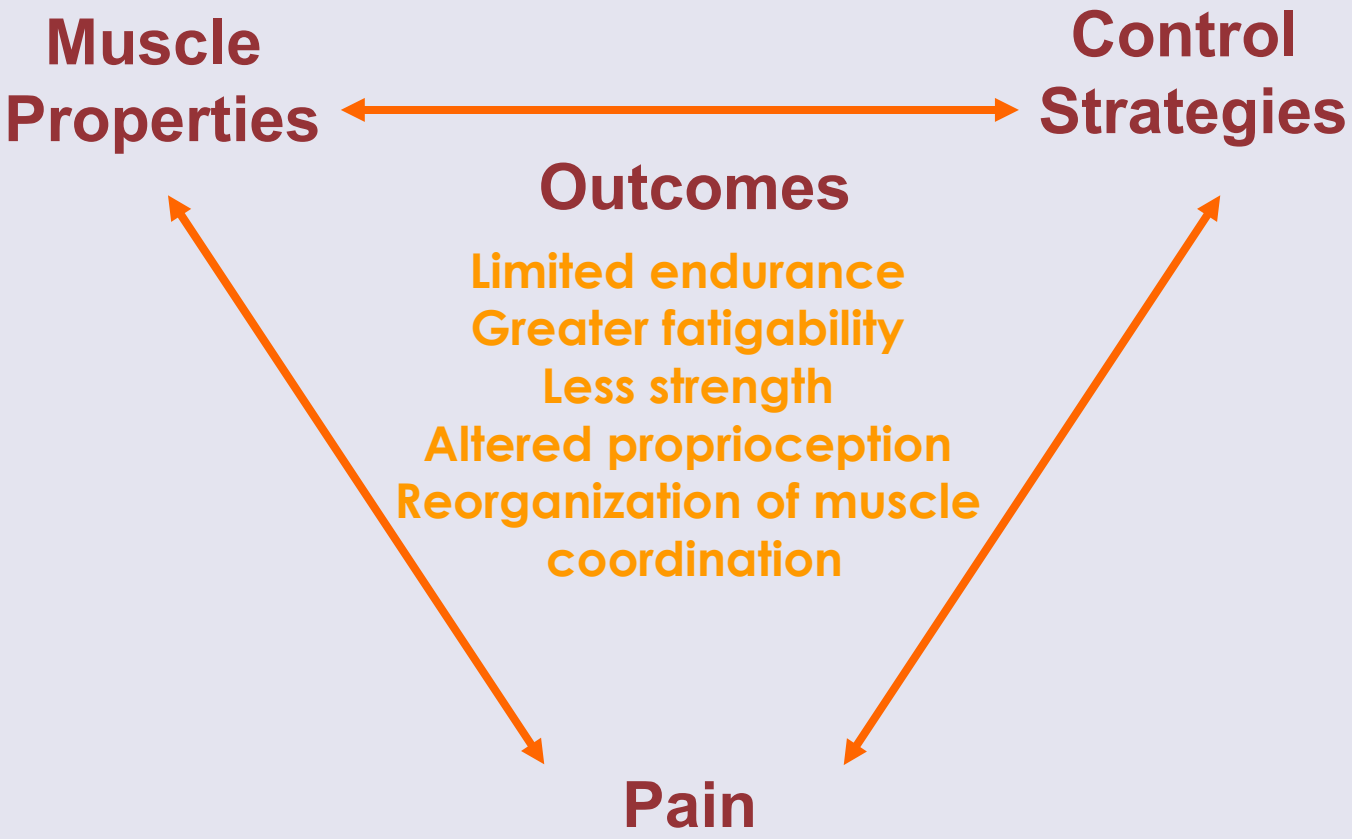
- Given the complexity of the cervical spine, it is expected that alterations in afferent feedback from the muscles, e.g. due to **pain**, induce major modifications of cervical **motor control**

- Indeed, changes in motor control of the cervical spine have been documented in people with neck pain

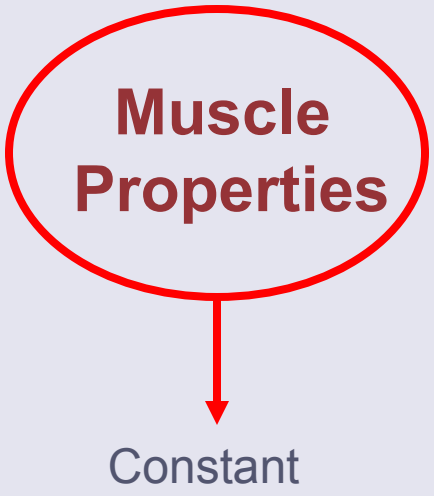
What are the changes in muscle function in the cervical region in the presence of pain?

What are the mechanisms underlying these changes?

Can musculoskeletal models help us to answer these questions?



Falla & Farina, Curr Rheum Rep, 2007



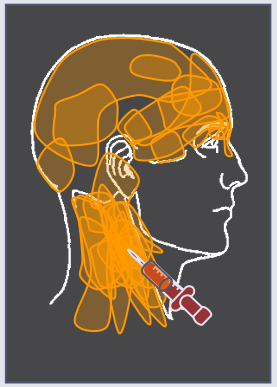
Control Strategies

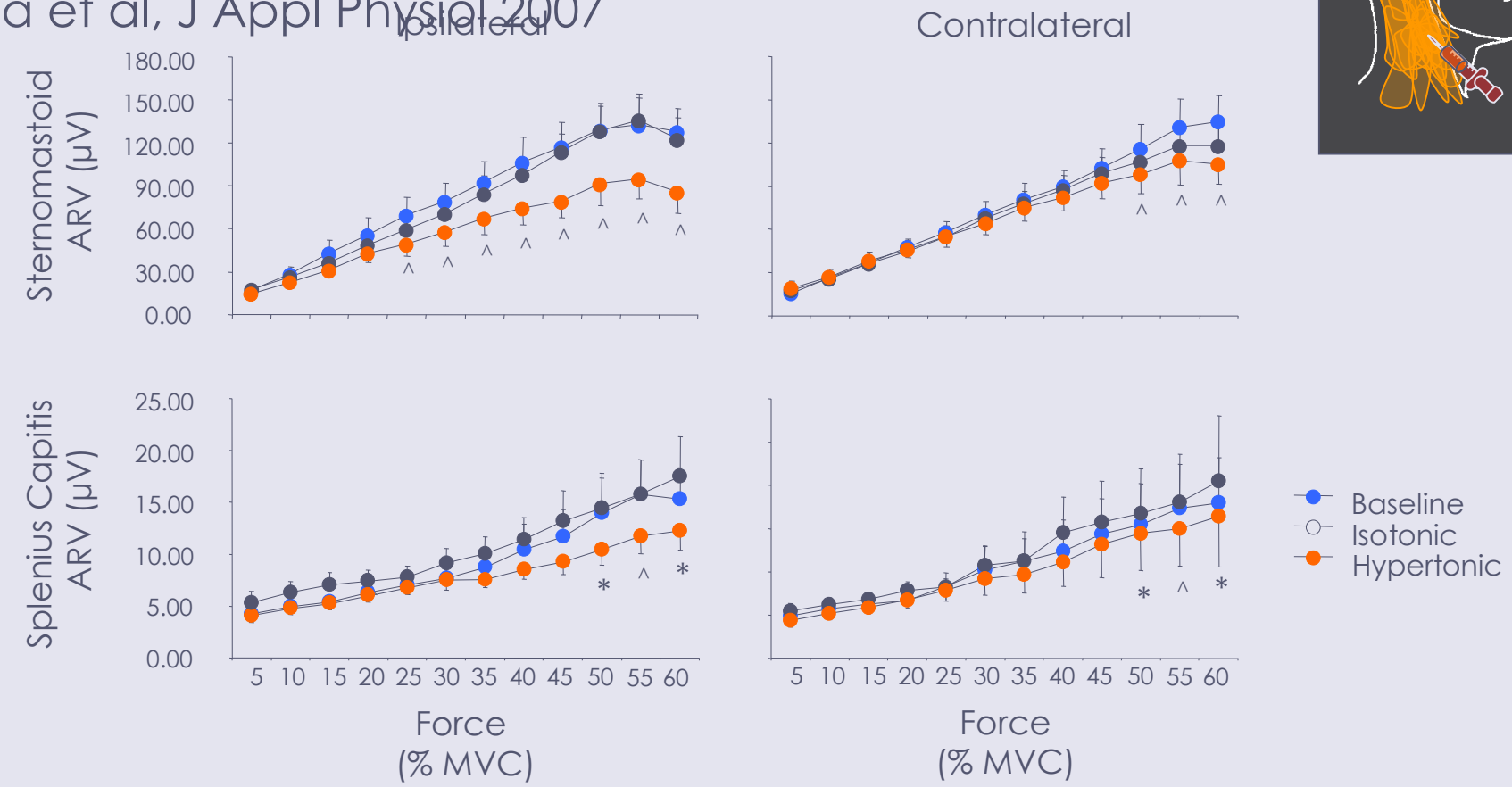
Pain

Experimental muscle pain ⇒
Injection with hypertonic saline

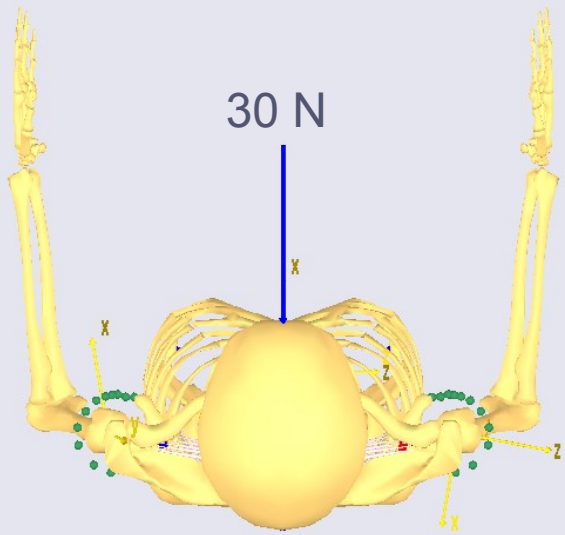
Cervical Flexion – Sternomastoid pain

Falla et al, J Appl Physiol 2007





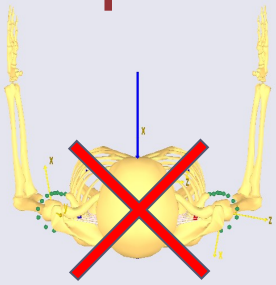
Input in the model



An external force of 30 N on the forehead to mimick isometric cervical flexion

No co-contraction of the sternomastoid and splenius capitis

Input in the model



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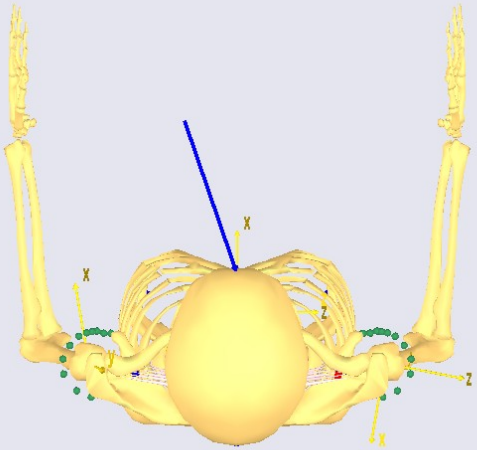

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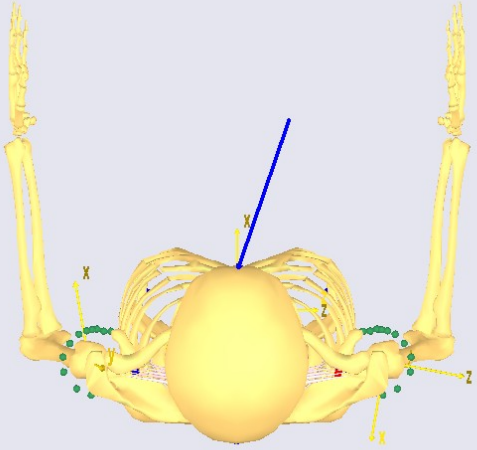
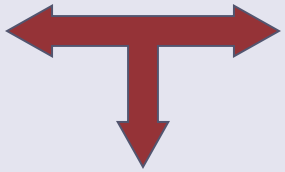
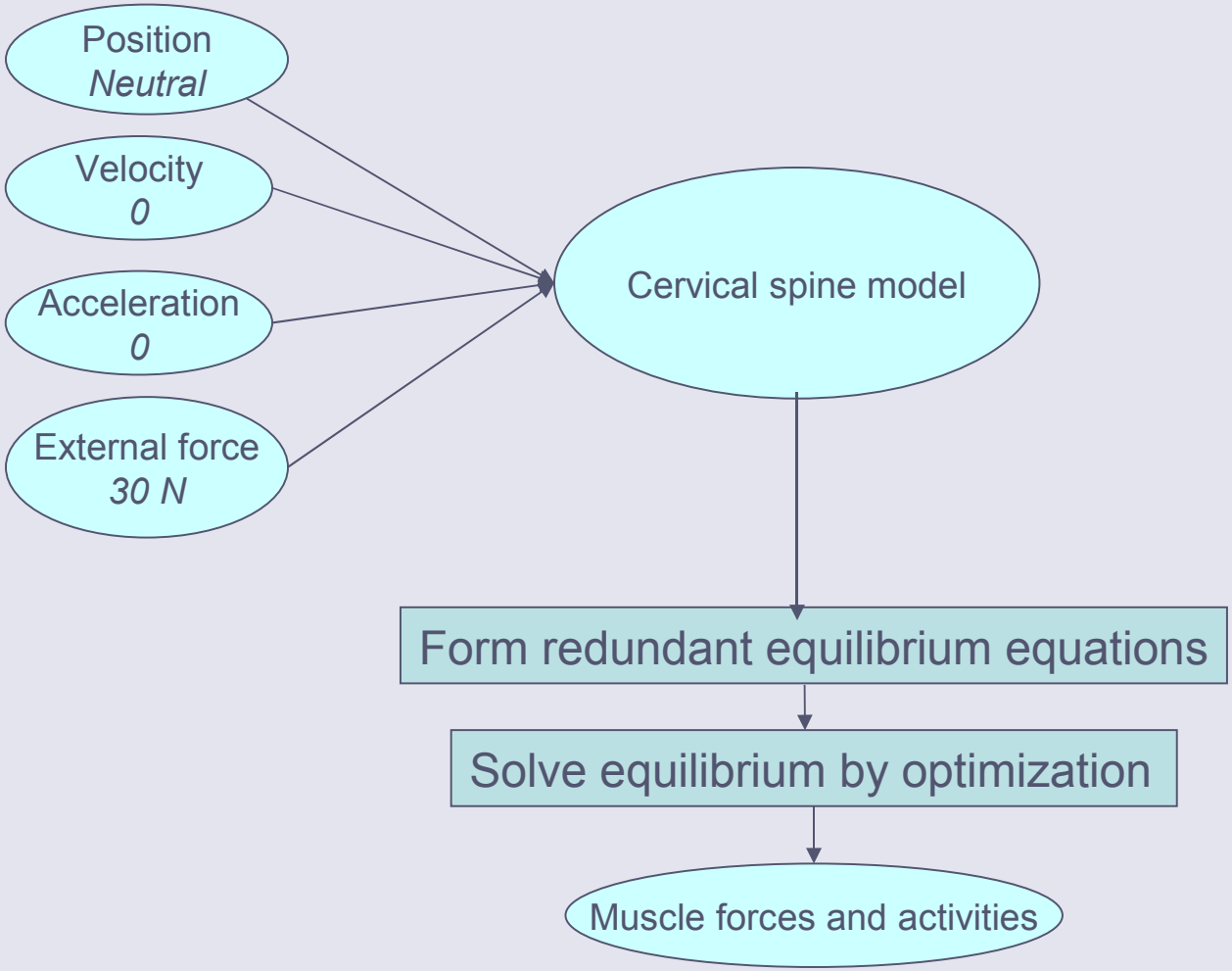


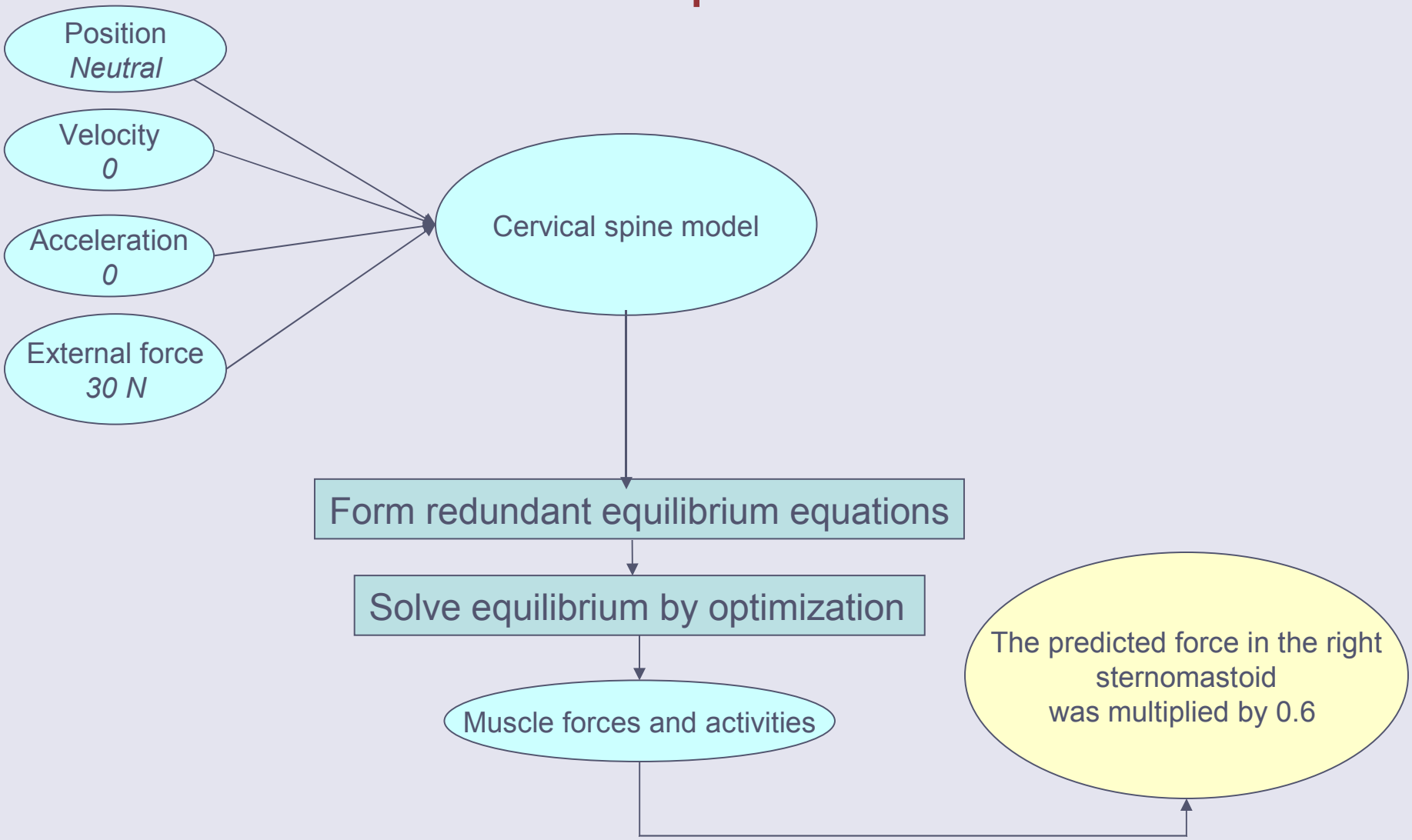


Average

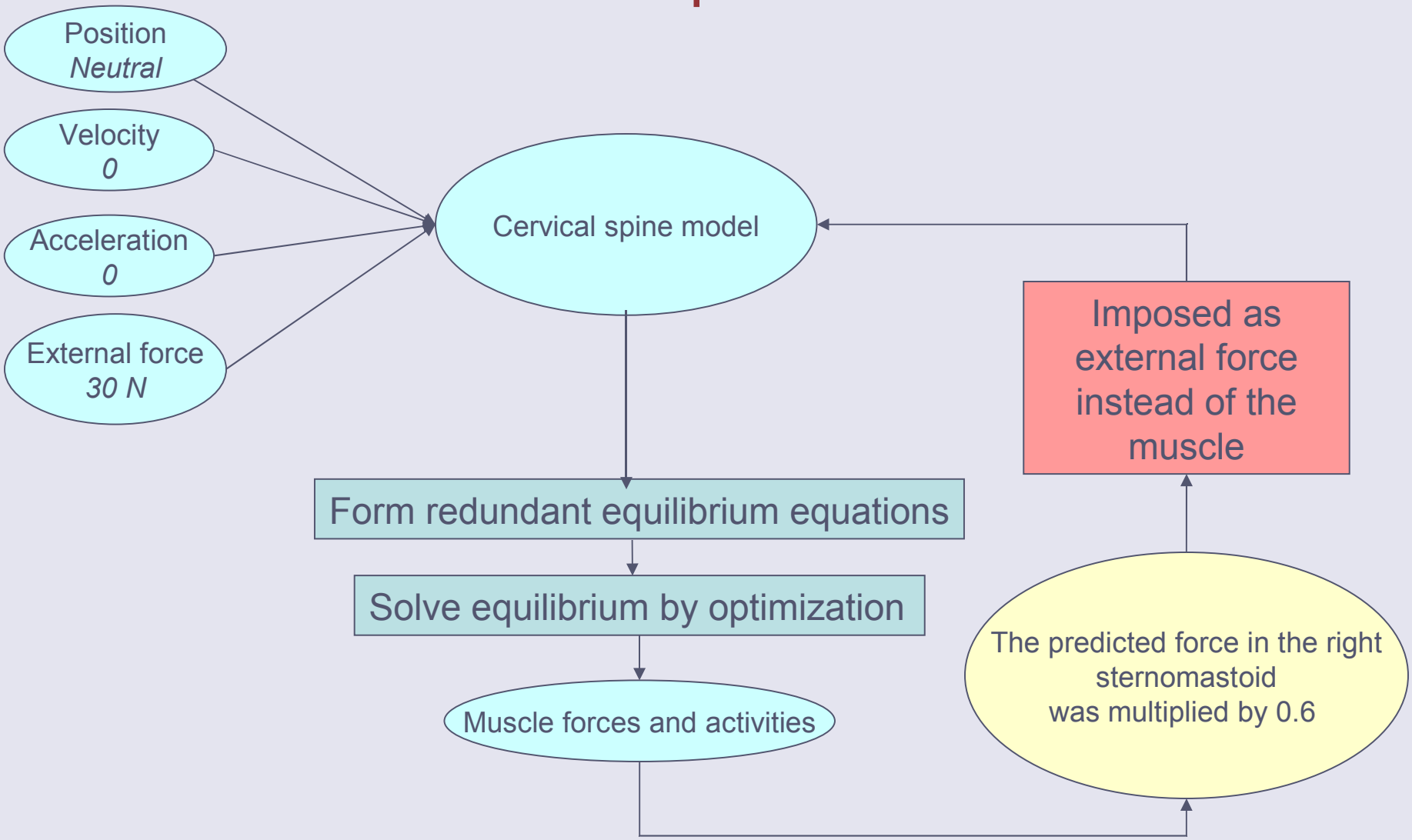
Calculation scheme – normal condition



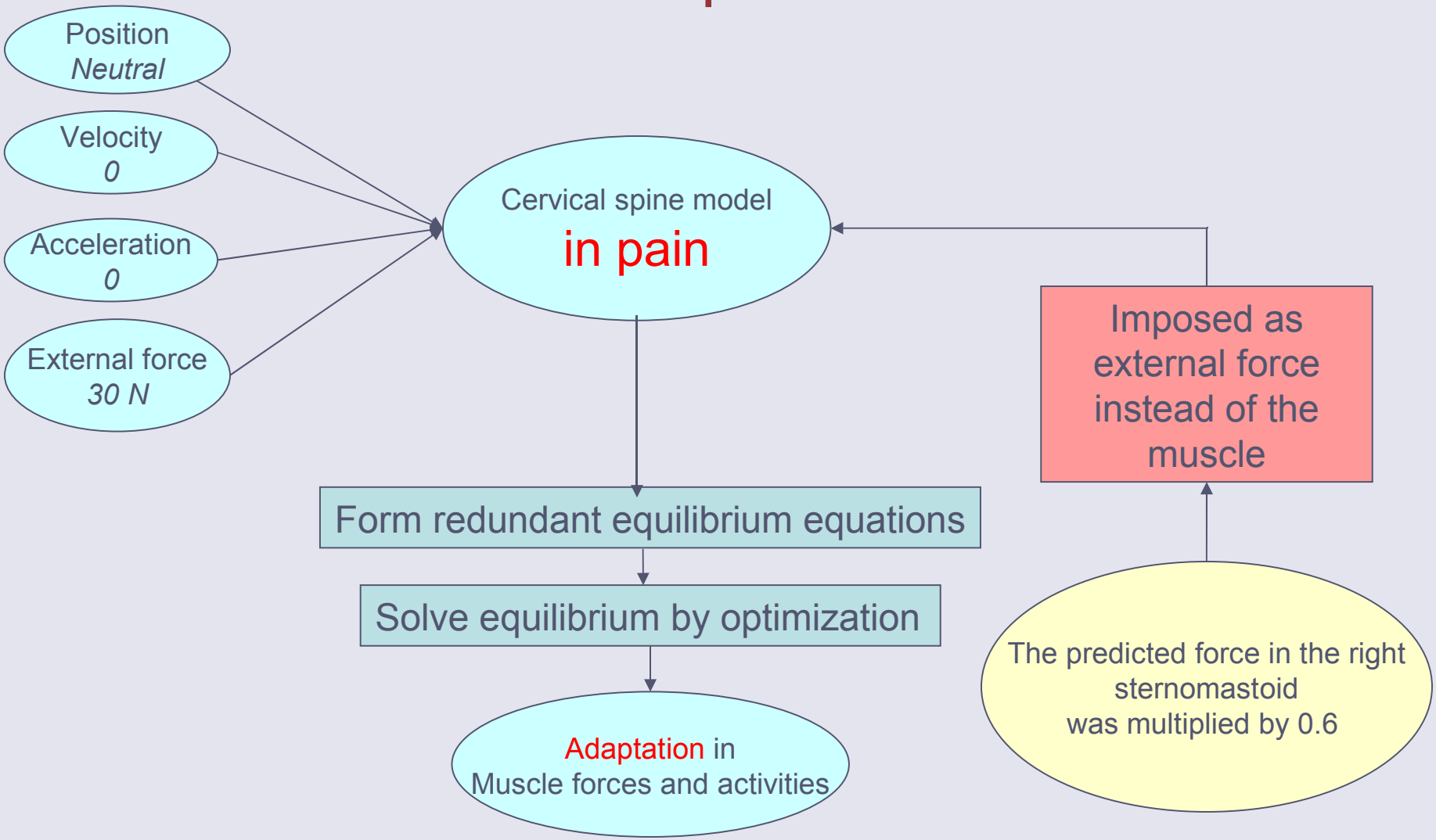
Calculation scheme – pain condition



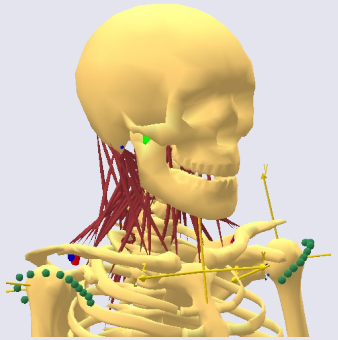
Calculation scheme – pain condition

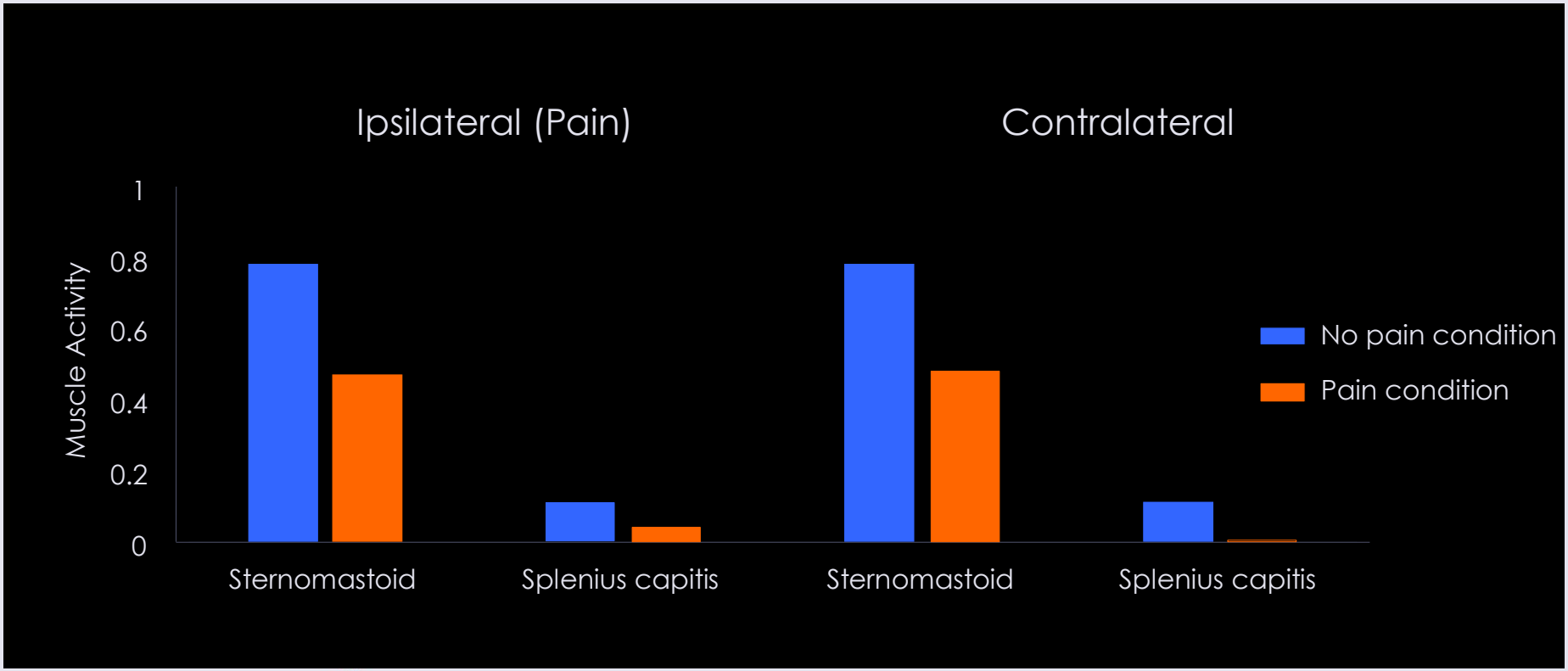


Calculation scheme – pain condition



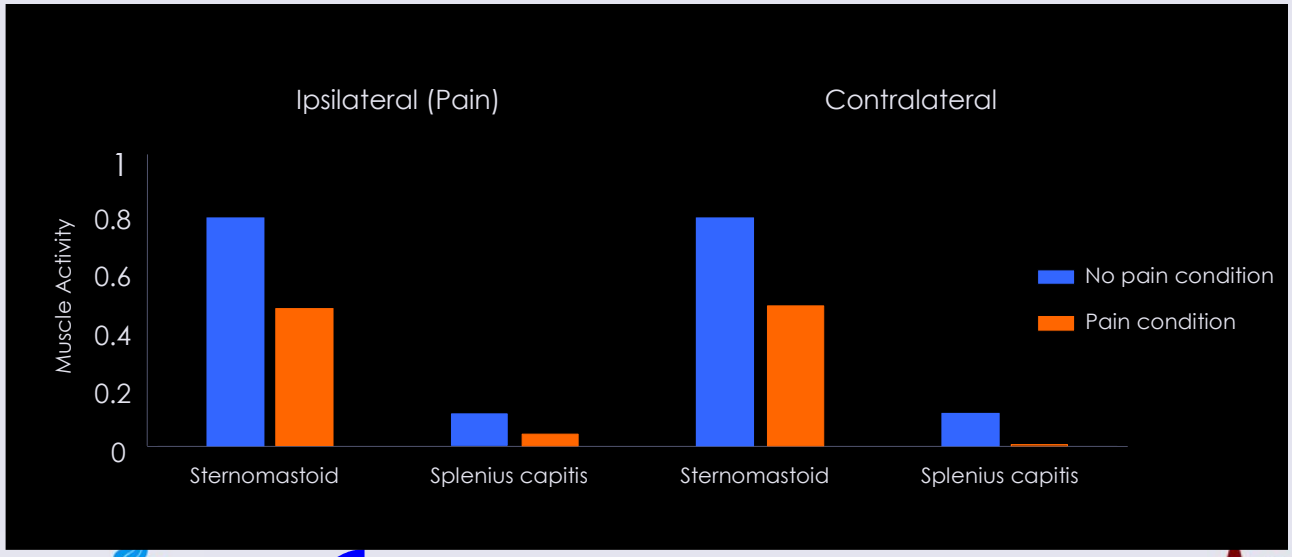
Cervical Flexion – Simulated sternomastoid inhibition





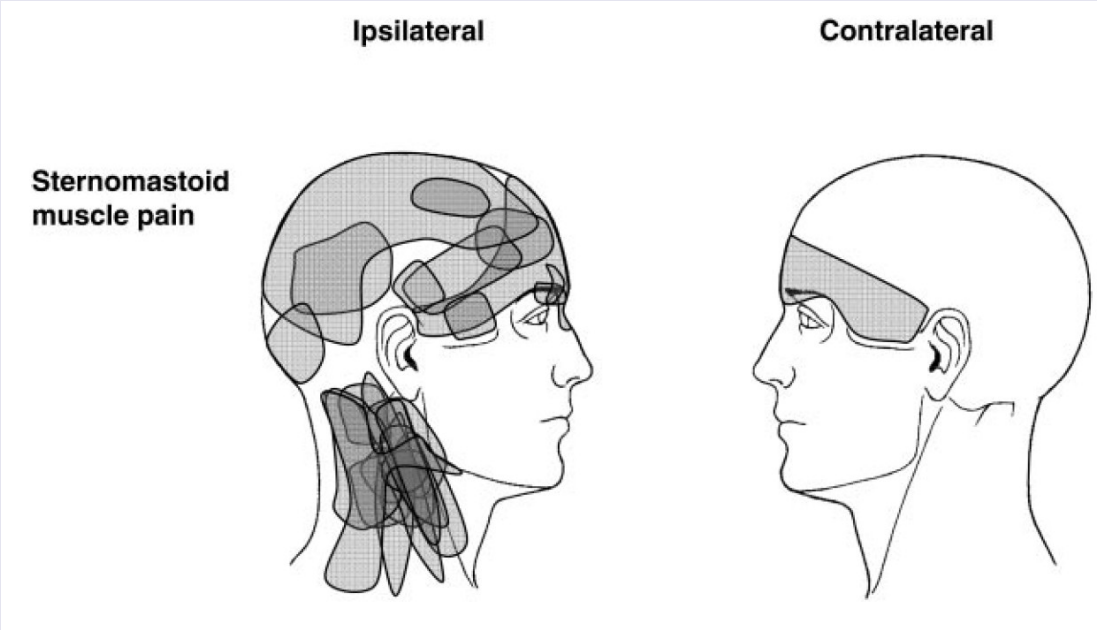
Discussion

- The simulation predicted an inhibition in the synergistic, contralateral sternomastoid and in the antagonist splenius capitis on both ipsilateral and contralateral side
- Suggesting that the CNS counteracts the inhibition of the painful muscle by choosing a muscle recruitment strategy of the remaining muscles, which minimizes fatigue



Discussion

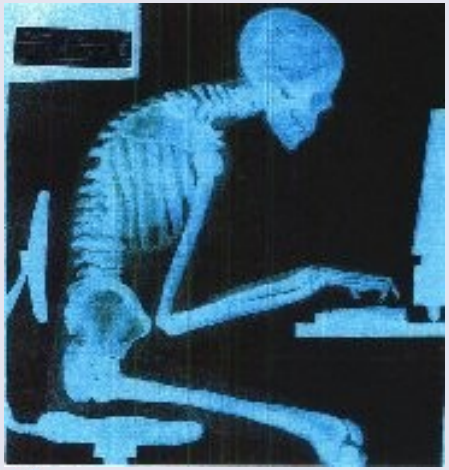
- The main assumption used was that we forced only the painful muscle to be less active. In reality a hypertonic saline injection in the sternomastoid muscle causes a quite large area of so-called referred pain



Falla et al, J Appl Physiol 2007

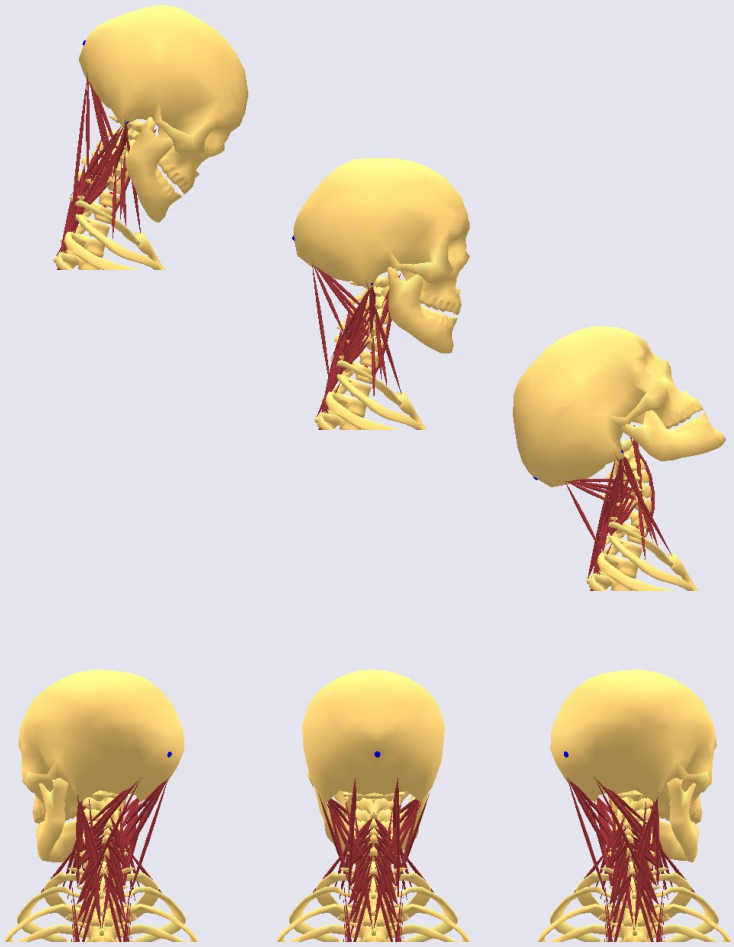
Conclusion

- Musculoskeletal models and the principles of biomechanics can help us to understand the change in muscle coordination
- And quantify the change in muscle loading in painful conditions



Future developments

- This model will become available in the public repository (www.anybody.aau.dk)
- More detailed validation experiments are planned
- With the use of wire electrodes to measure EMG
- Inclusion of facet joints is planned



Thanks!

- Center for Sensory-Motor Interaction, Aalborg University
  www.smi.hst.aau.dk

- The AnyBody Modeling System
  www.anybodytech.com

- The AnyBody Research Project, Aalborg University
  www.anybody.aau.dk

Acknowledgements

RBM A/S and AP Furniture A/S

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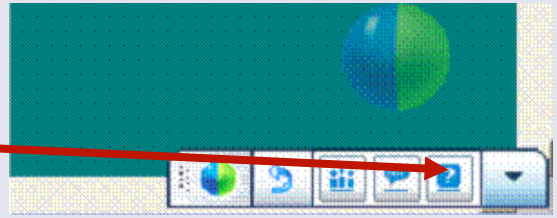

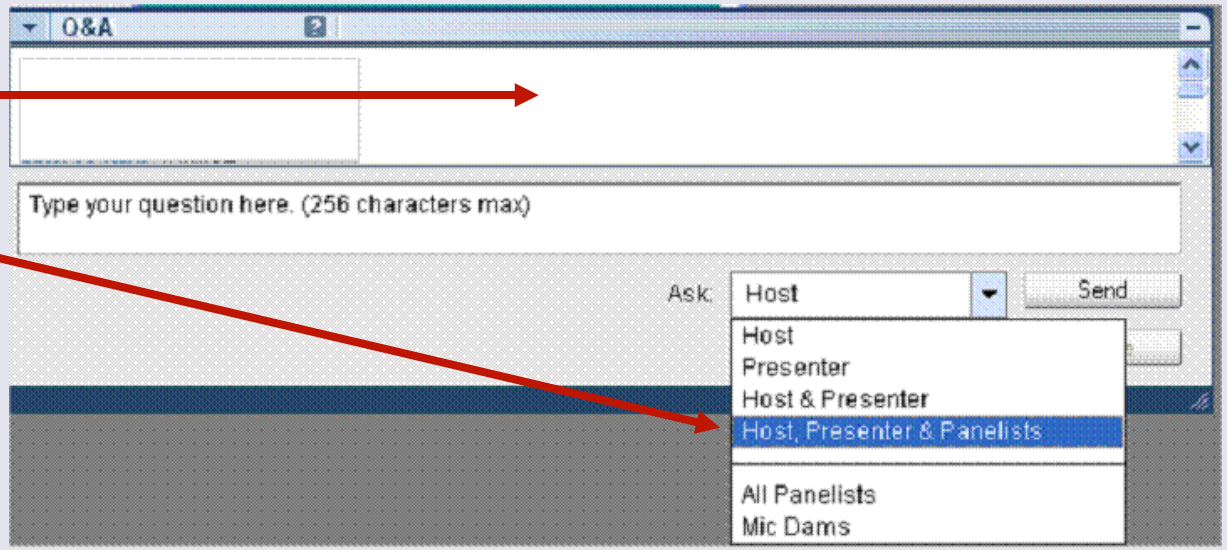

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