The effect of follower load on the intersegmental coupled motion behaviour of the human thoracic spine

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Current state of research

- Mechanical coupling between lateral bending and axial rotation

  In vivo: …, Fujimori et al. (2012, 2014), Moon et al. (2014)

  In vitro: …, Brasiliense et al. (2011), Mannen et al. (2015)

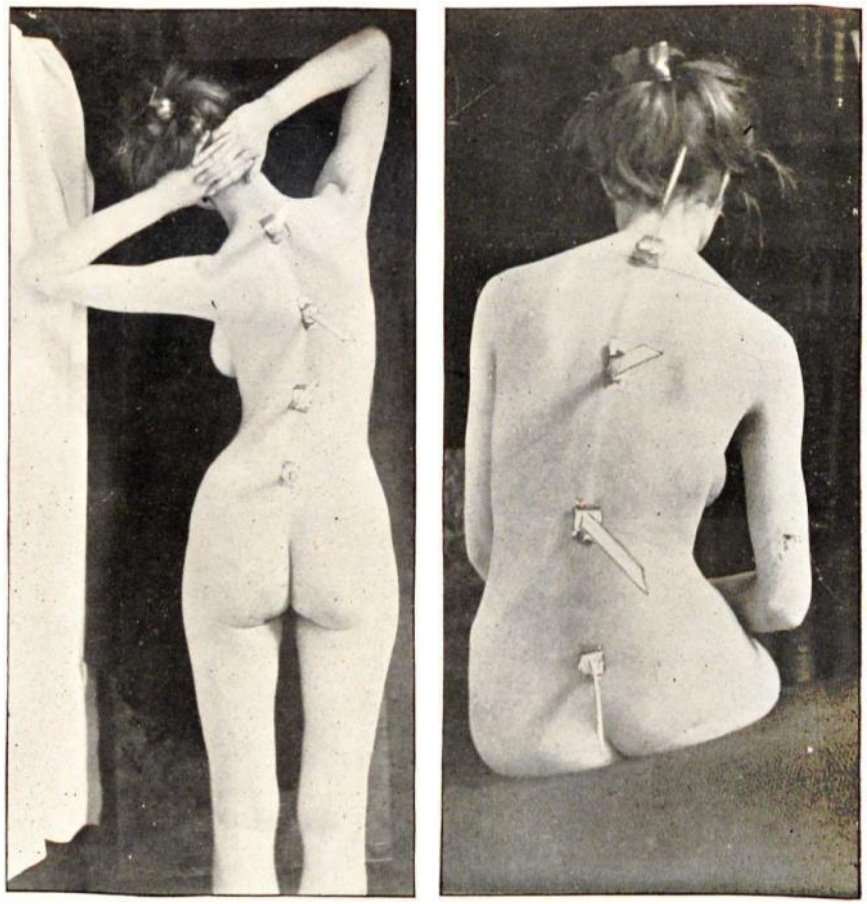
  In silico: Scholten and Veldhuizen (1985)

- Wide variations / no information regarding

  - extent of segmental coupling
  - direction of secondary motions during primary bending in one direction

↓

Validation of numerical models ?
Interpretation of implant testing ?



Lovett (1900)

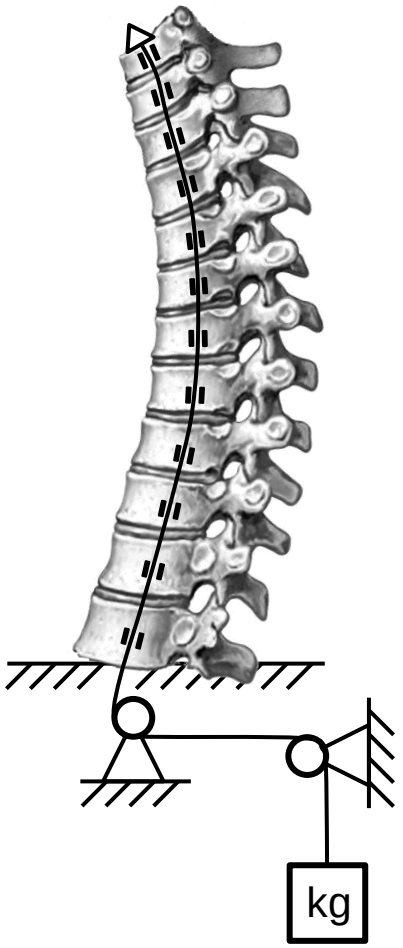
Current state of research

Effects on coupled motion behaviour of the thoracic spine:

- Sagittal position of the thoracic spine in vivo
  Lovett (1900), Edmondston et al. (2007), Moon et al. (2014)
- Activity of the subjects during in vivo trials
  (standing, sitting, walking, weight carrying, …)
  Gregersen and Lucas (1967)

→ In vitro tests under quasi-physiological conditions
to reach better comparability between in vitro and in vivo findings

→ Simulation of quasi-physiological loading in the spine:
Follower loading Patwardhan et al. (1999)



Effects of follower loading on the biomechanics
of the thoracic spine including the intact rib cage:

- Stiffness ↑ Sis et al. (2016)
- Intradiscal pressure ↑ Anderson et al. (2016, 2017)
- Coupled motion behaviour ?

Purposes of the study

Quantitative determination of

- the thoracic spinal coupled motion behaviour under defined boundary conditions
- the effect of follower loading on the coupled motion behaviour
- the intersegmental motion behaviour of all thoracic spinal motion segments including the intact rib cage

  - without follower load
  - with follower load

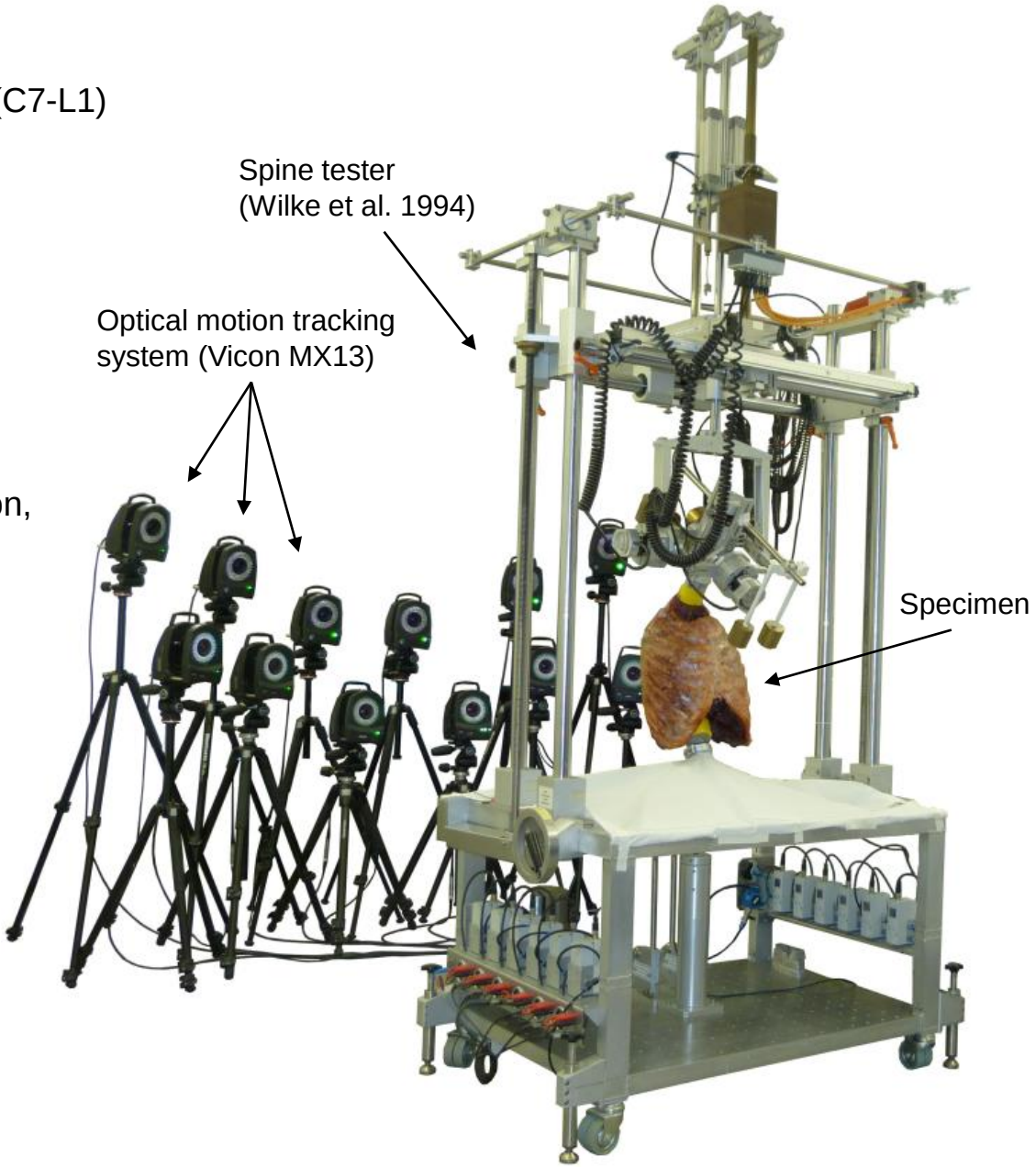
  in order to generate data for the validation of finite element models

Specimens

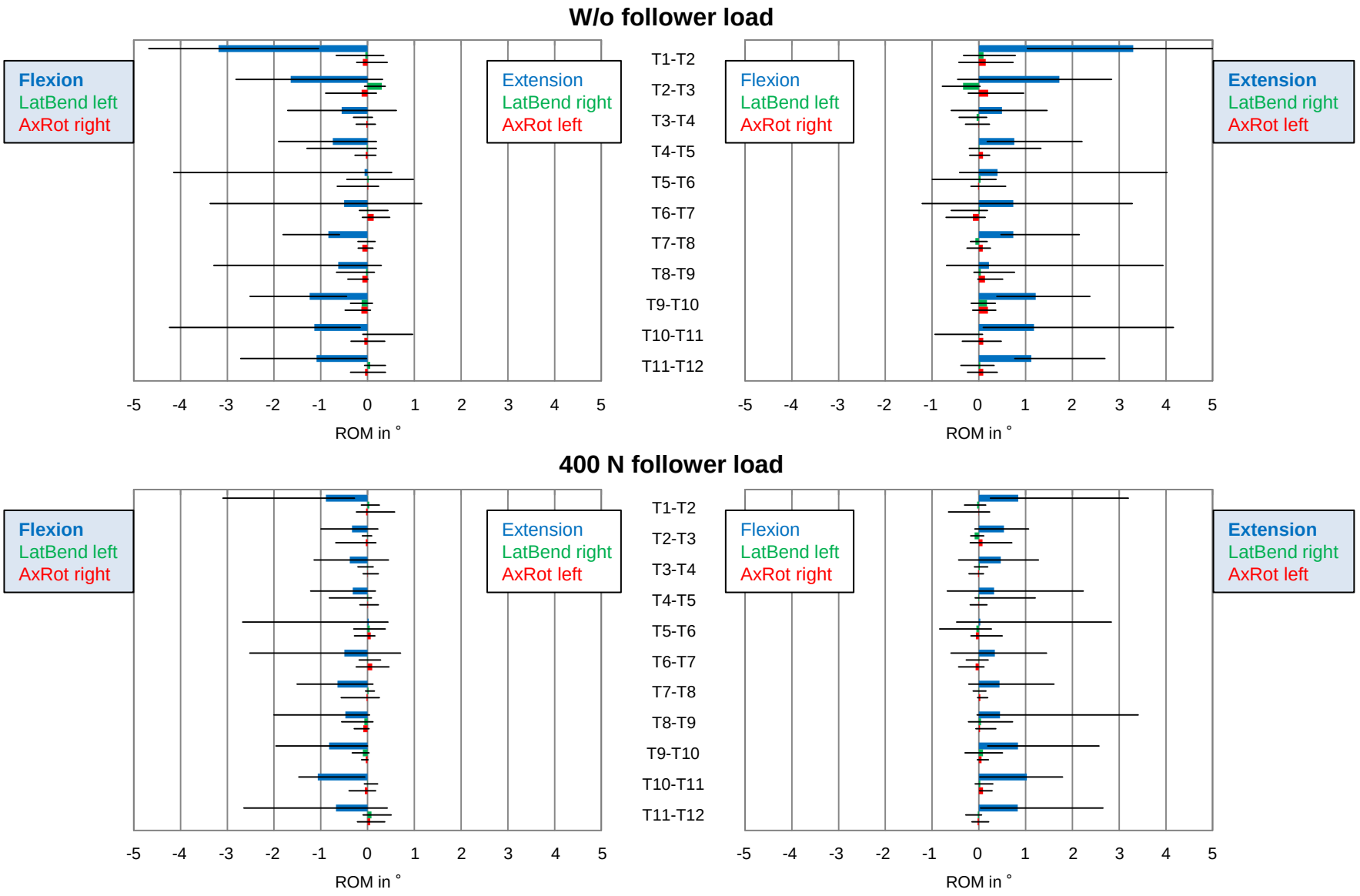
- 8 fresh frozen human thoracic spines (C7-L1) including intact rib cage
- Mean age 54±6 years (40-60 years)
- 7 male, 1 female

Mechanical testing

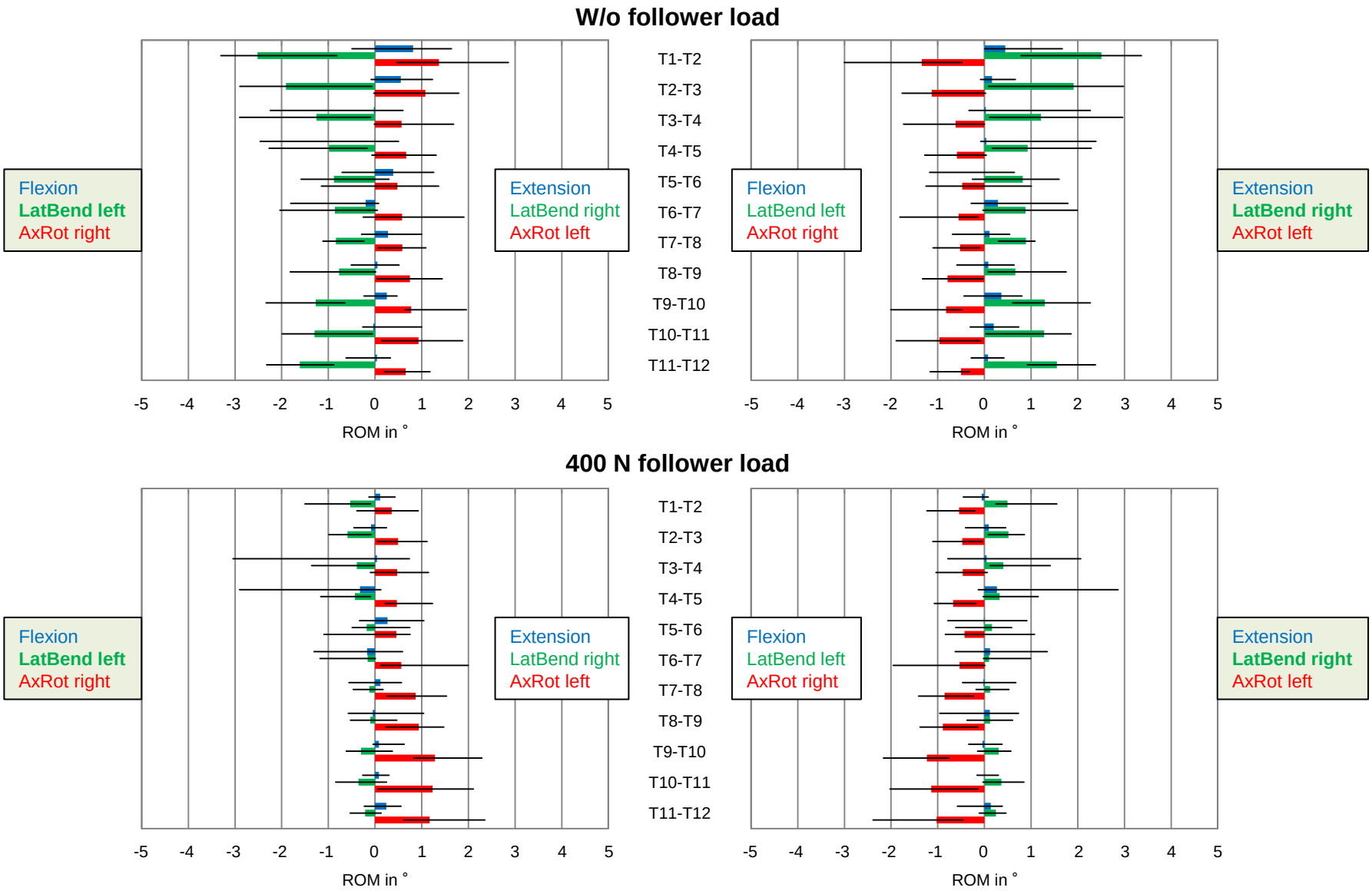
- Quasi-static loading in flexion/extension, lateral bending, and axial rotation:
  - Pure moments of 5 Nm
  - Angular velocity of 1°/s
  - 3.5 loading cycles
- Testing order:
  - Without follower load
  - With follower load (400 N)
- Measurement of:
  - Primary (in-plane) motions
  - Secondary (out-of-plane) motions



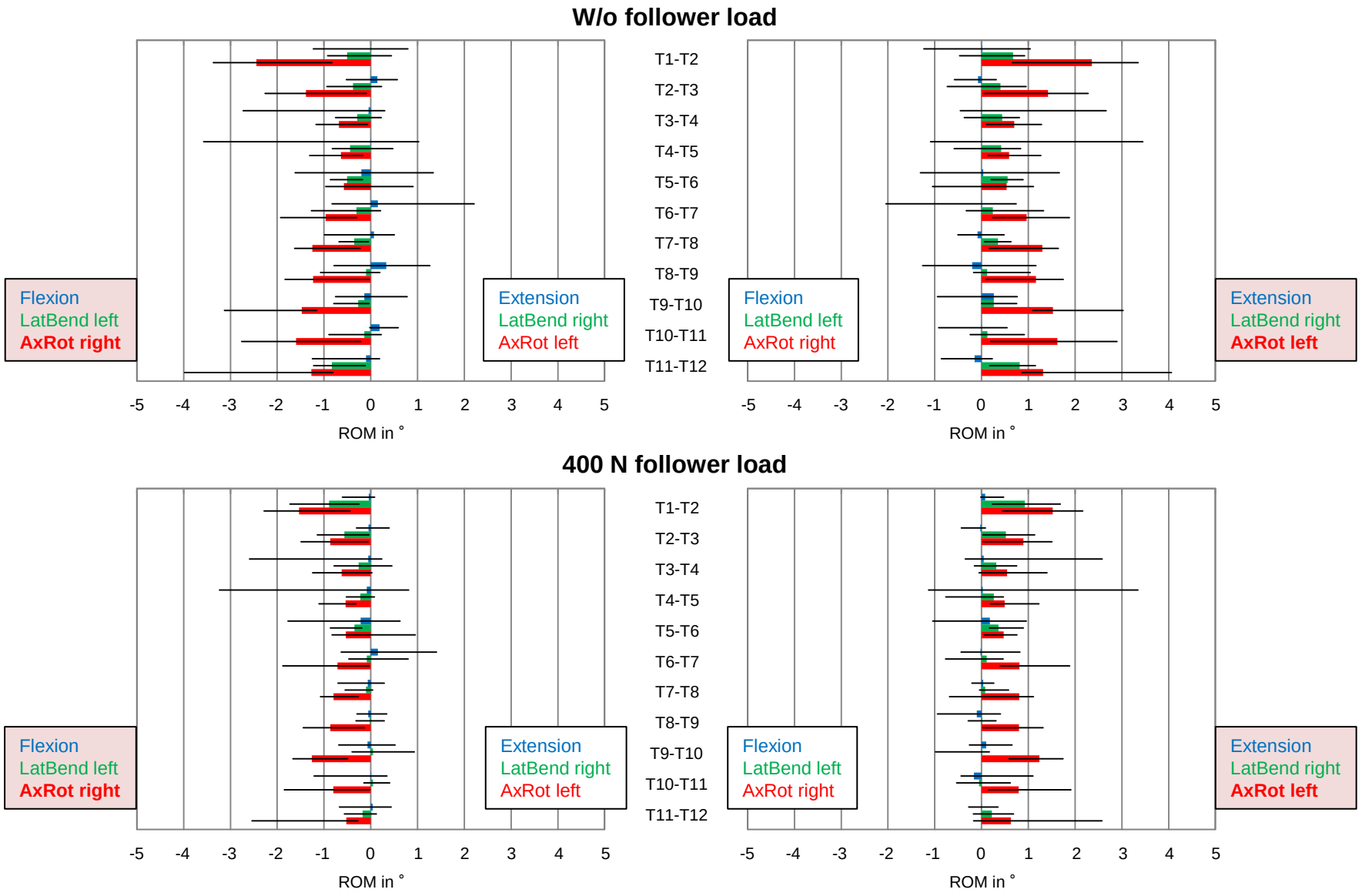
Flexion/extension



Lateral bending



Axial rotation

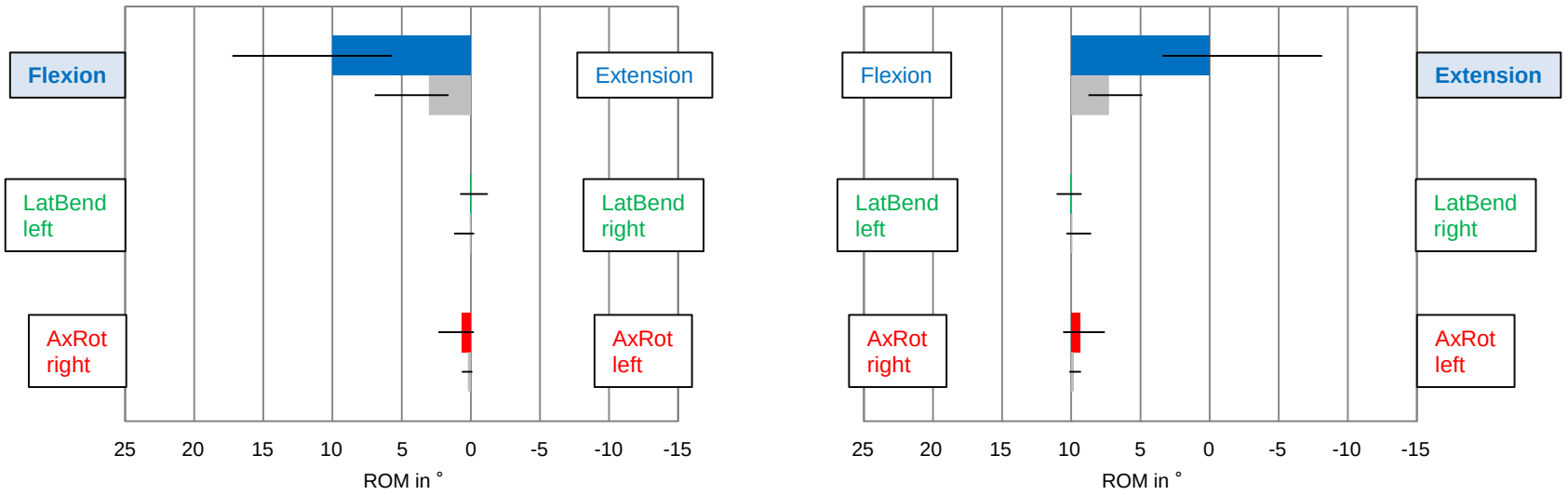


Flexion/extension (T1-T12)

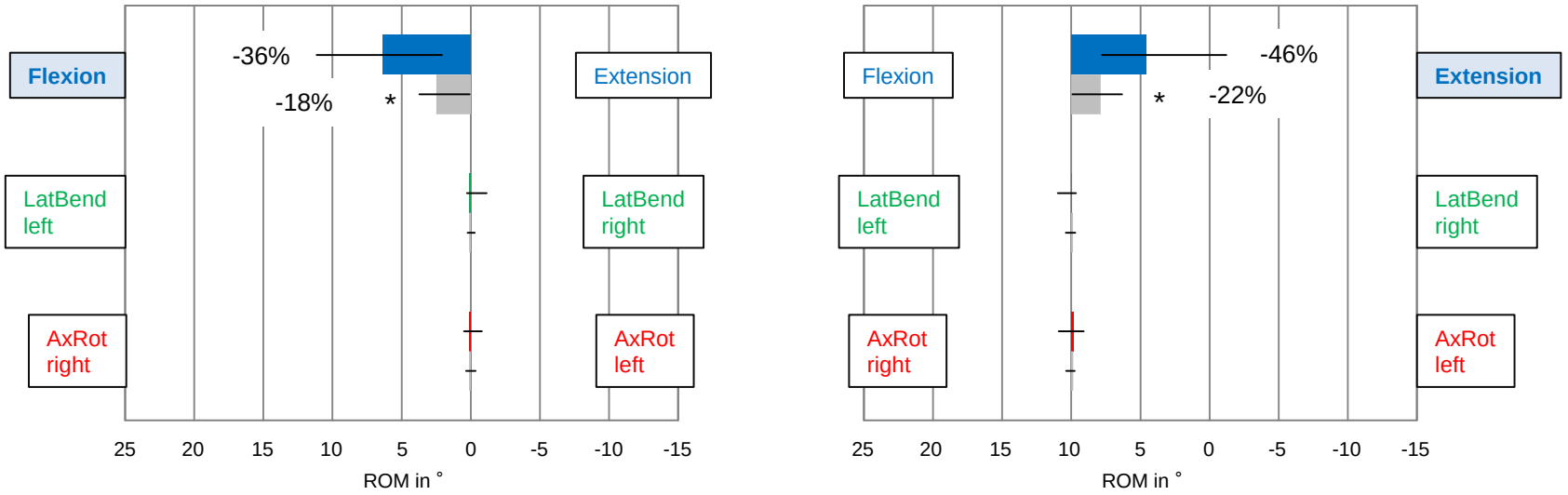
ROM
NZ

* p < 0.01 (Friedman test)

W/o follower load



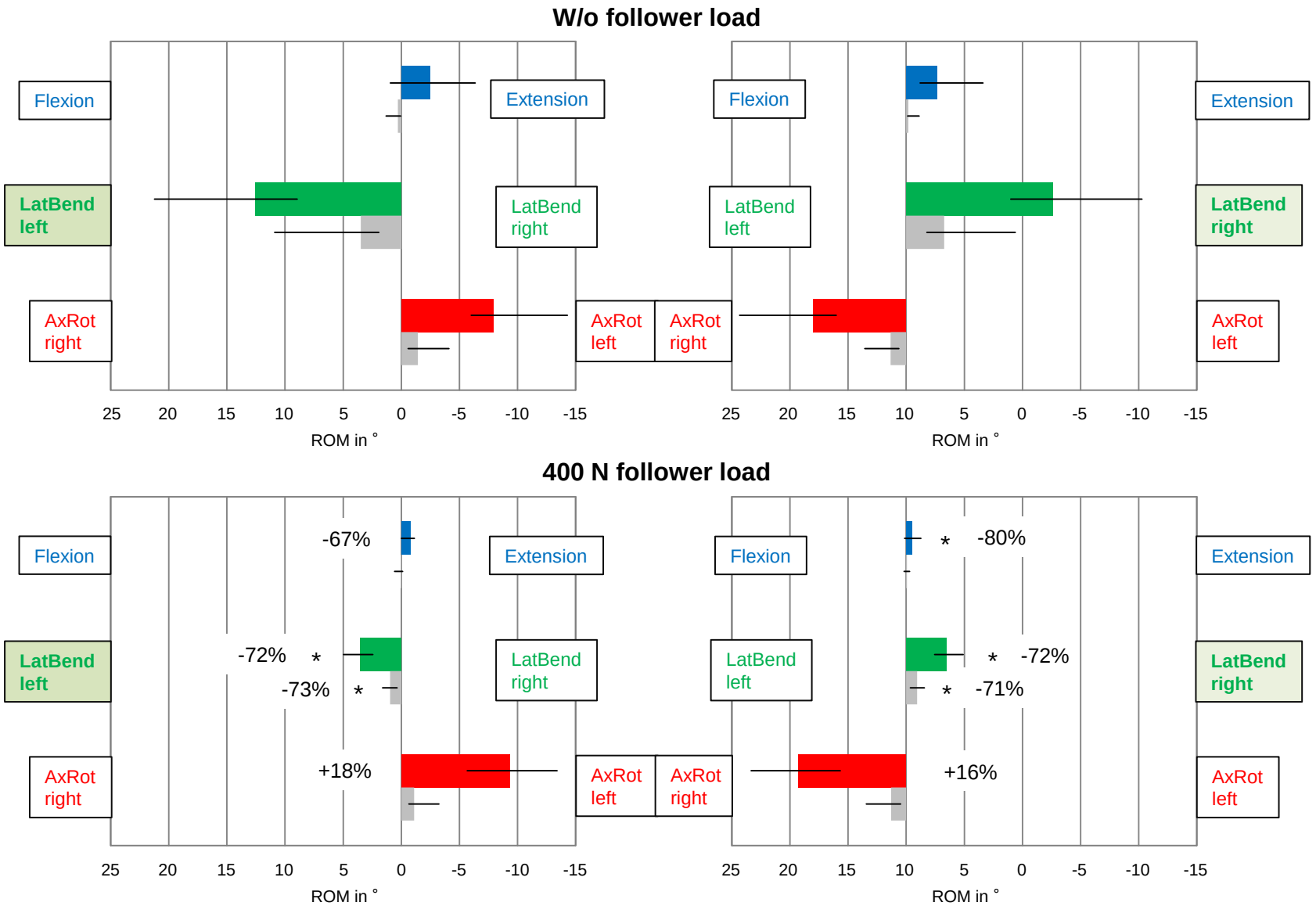
400 N follower load



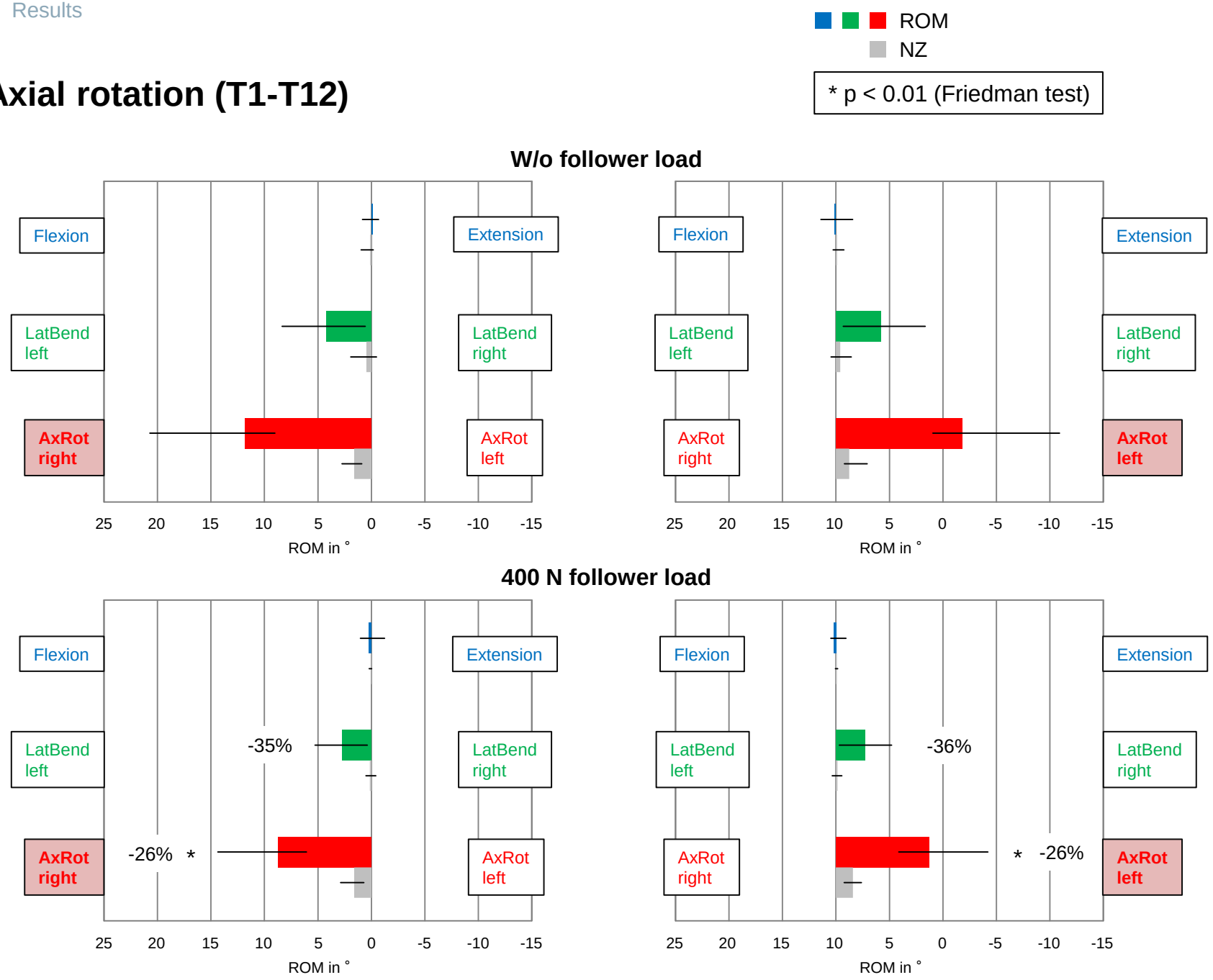
Lateral bending (T1-T12)

ROM
NZ

* p < 0.01 (Friedman test)



Axial rotation (T1-T12)



Interpretation

Effects of follower loading:

- Intersegmental motions from T1 to T12 almost equally distributed
  → Physiological loading compensates higher motions in upper motion segments
- No coupled motions during primary flexion/extension
  → Maximum flexibility ensured in this motion plane
- Primary lateral bending significantly reduced, secondary axial rotation increased
  → Lateral bending directly transferred into axial rotation
  → Physiological lateral bending apparently no intrinsic motion (Lovett 1900)
  → Lateral parts of the spine / rib cage saved from excessive deformation

Summary

- Follower loading
  - decreases all primary and secondary motions except secondary axial rotation during primary lateral bending
  - leads to an almost equal distribution of intersegmental motions
- Validation of numerical models can be performed more accurately and physiologically using these data

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ufb ulm