Motor control and low back pain

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ccre spine centre of clinical research excellence
Spinal Pain, Injury & Health NHMRC funded centre
The University of Queensland Australia

TOPICS FOR DISCUSSION

1. Coordination of multiple functions of trunk muscles
2. Assesment and Training of respiratory muscles
3. Activation of trunk muscles
4. Multifidus: Dysfunction and Rehabilitation
5. Effects of training

Coordination of multiple functions of trunk muscles

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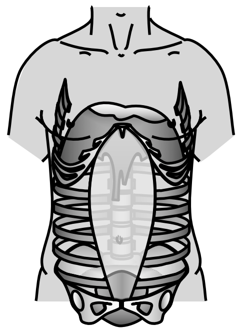
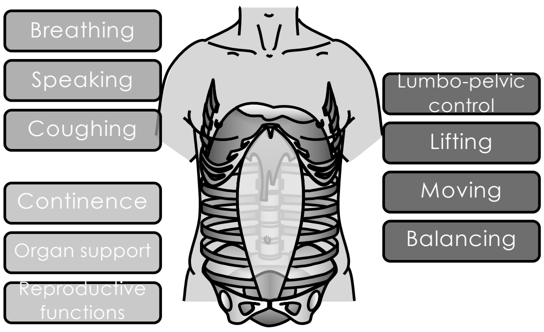
Control of an integrated system



Control of pressures is important for many functions



Outline

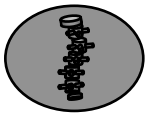
Normal integration of multiple functions of pelvic & trunk muscles

Dysfunction of multiple functions of pelvic & trunk muscles

Implications for rehabilitation

Outline

Normal integration of multiple functions of pelvic & trunk muscles



Lumbopelvic control

Optimal motor control involves:
#1: Balance between movement & stiffness

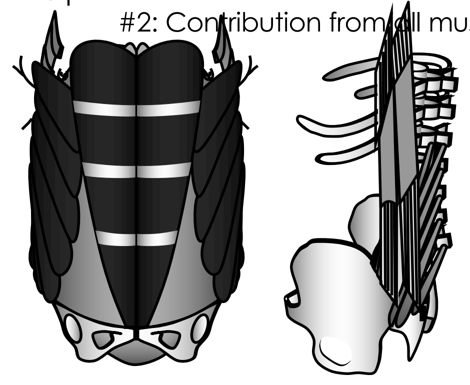
Diane Lee, Vancouver, Canada

Optimal motor control involves:
#1: Balance between movement & stiffness

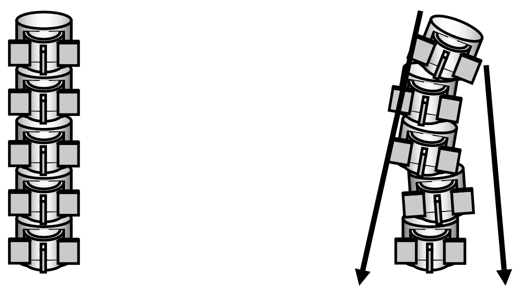
STIFFNESS
- Maintain alignment
- Control translations

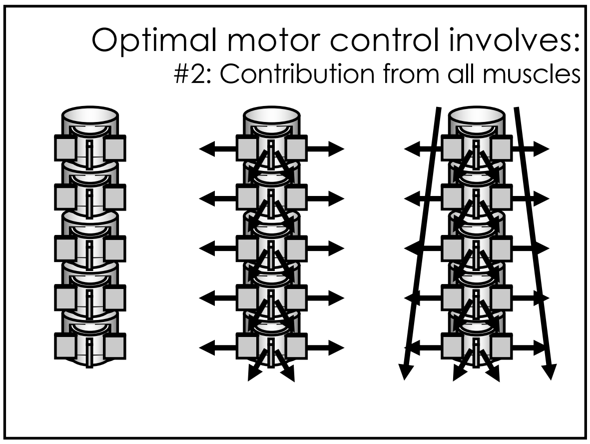
MOVEMENT
- Motion for function
- Motion for shock absorption/force damping
- Motion for load transfer
- Distribute load between adjacent segments (spine regions, limbs) for load sharing
- Variation - necessary for load sharing

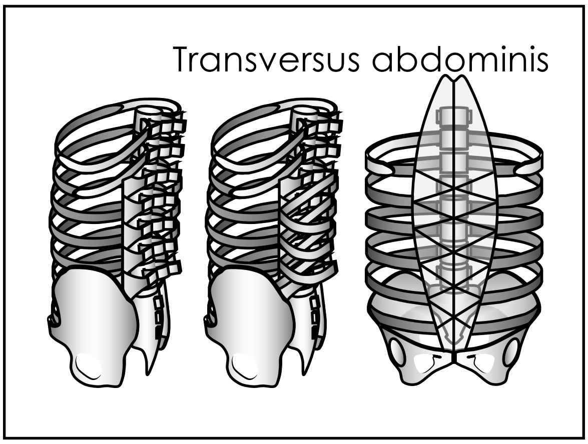
Optimal motor control involves:
#2: Contribution from all muscles

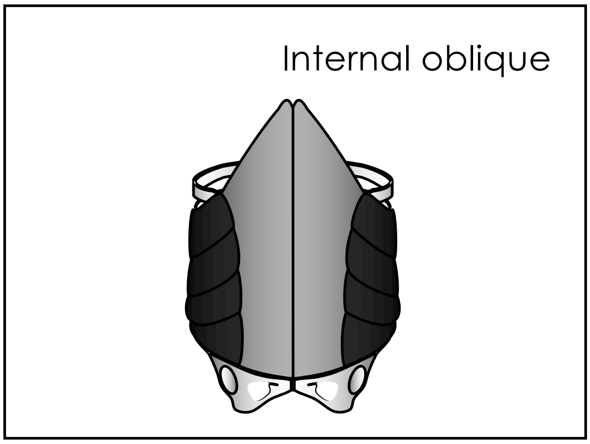


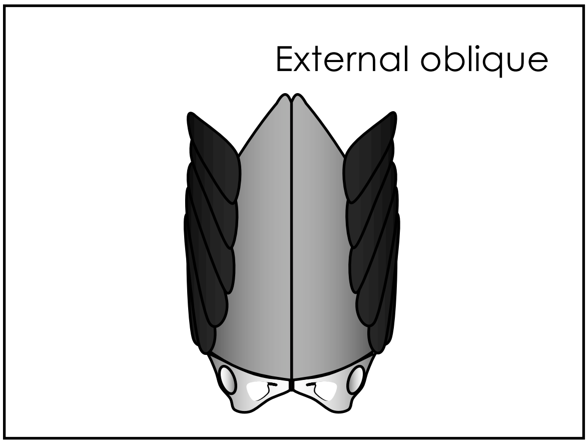
Optimal motor control involves:
#2: Contribution from all muscles

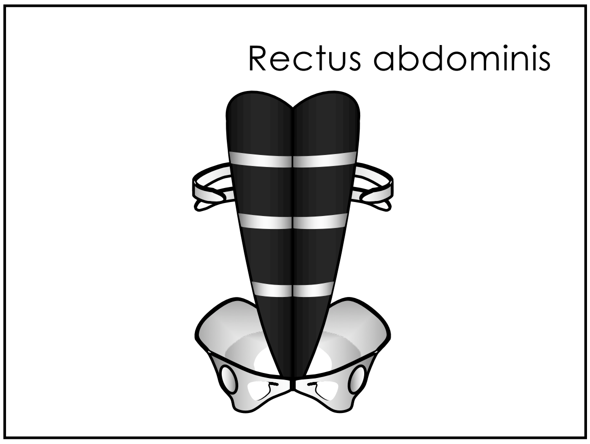


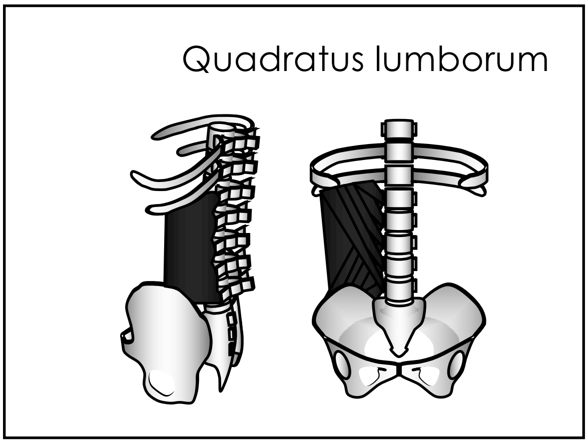

Optimal motor control involves:
#2: Contribution from all muscles


Transversus abdominis

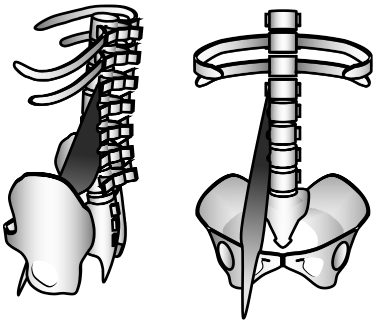

Internal oblique


External oblique

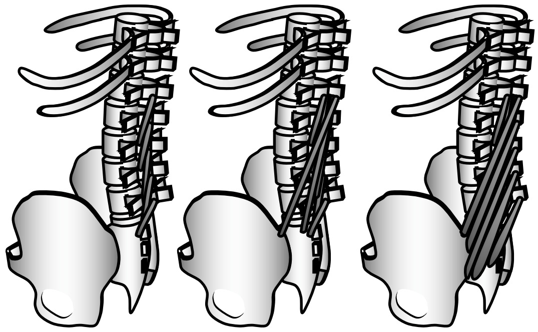

Rectus abdominis


Quadratus lumborum

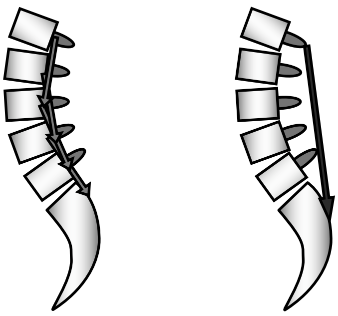
Psoas major



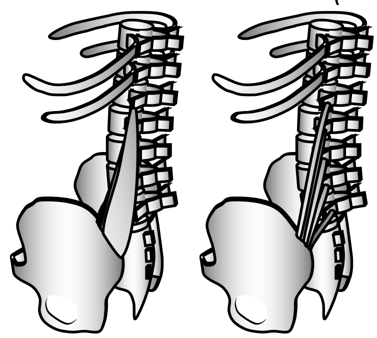
Lumbar multifidus



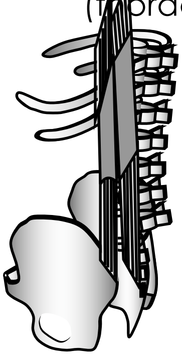
Deep vs. superficial multifidus



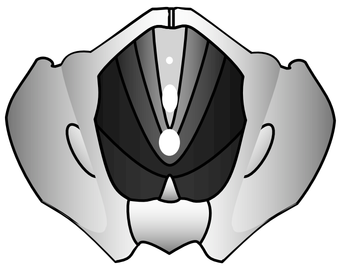
Longissimus & iliocostalis
(lumbar)



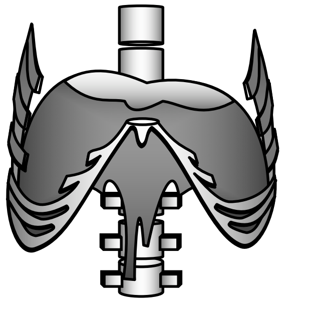
Longissimus & iliocostalis
(thoraco-lumbar)



Pelvic floor muscles

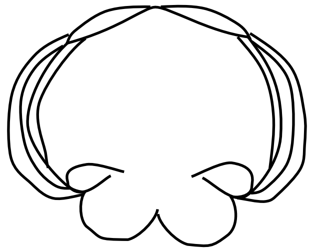


Diaphragm



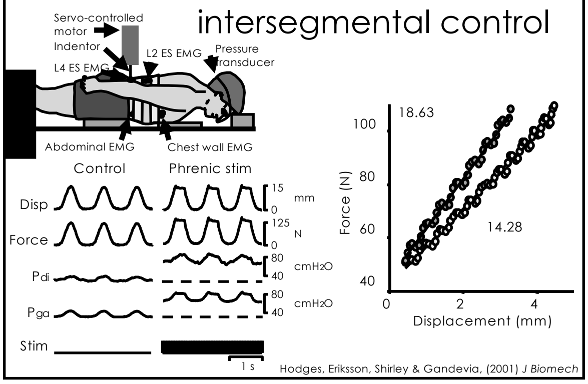
Optimal motor control involves:

#3: Involves fascia & intra-abdominal pressure



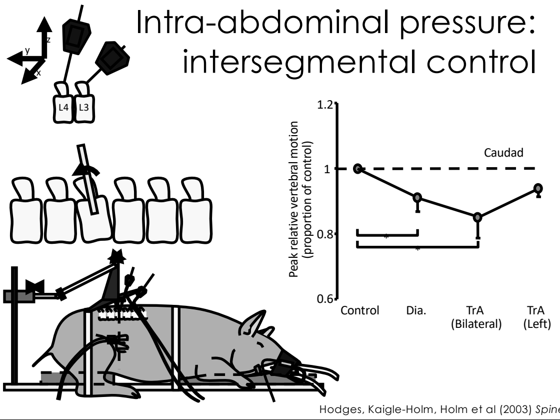
Does intra-abdominal pressure contribute to lumbopelvic control?

Intra-abdominal pressure: intersegmental control

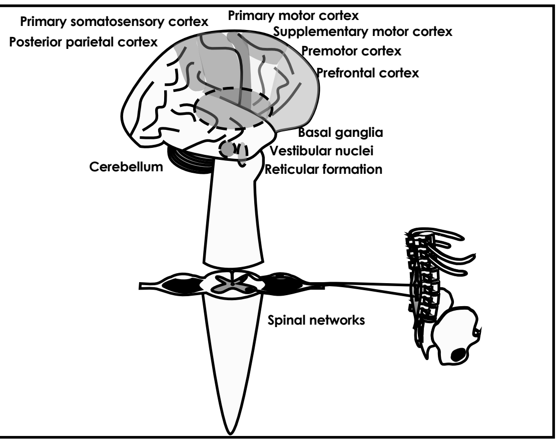


Hodges, Eriksson, Shirley & Gandevia, (2001) *J Biomech*

Intra-abdominal pressure: intersegmental control

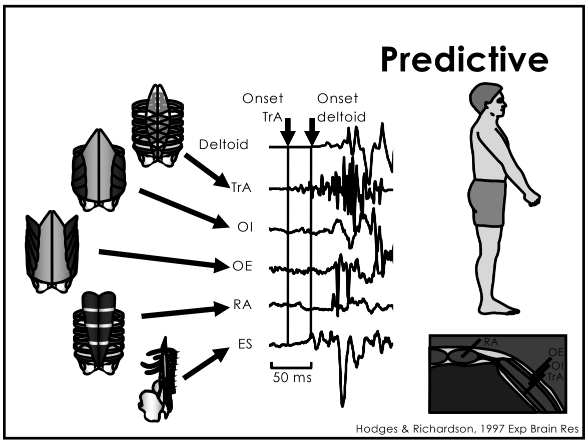


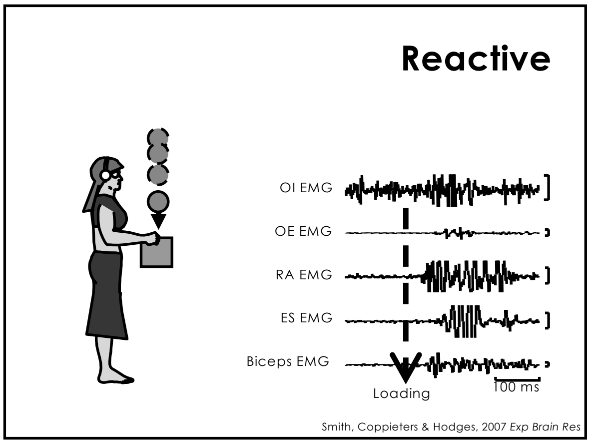
Hodges, Kaigle-Holm, Holm et al (2003) *Spine*

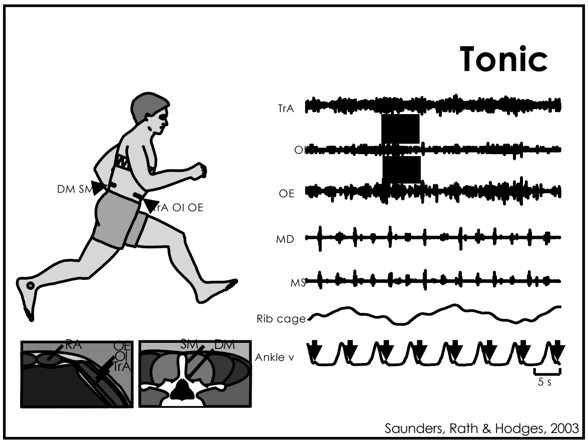


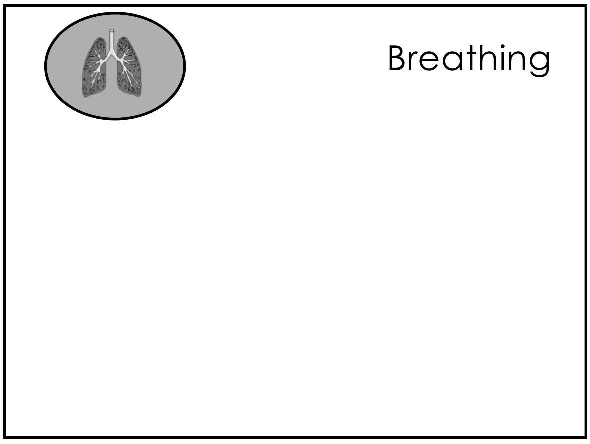
Optimal motor control involves:
#4: Three basic control strategies

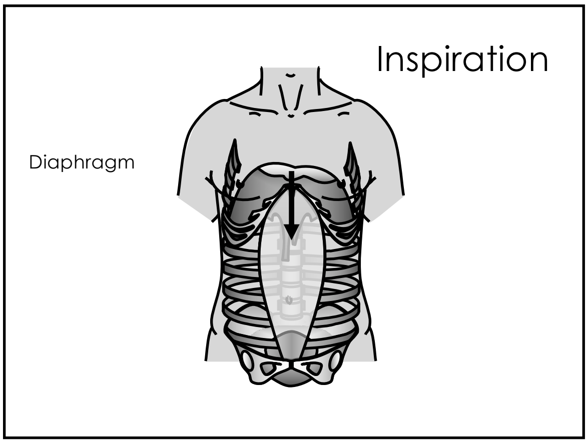
- **Predictive**
  - Feedforward control – based on experience
- **Reactive**
  - Feedback loops – simple (fast); complex (slow)
- **Tonic**
  - Modulation of intrinsic properties – inc. muscle stiffness/tone – ongoing

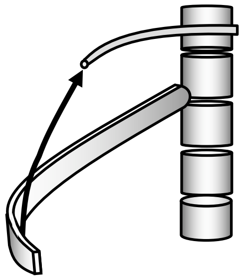


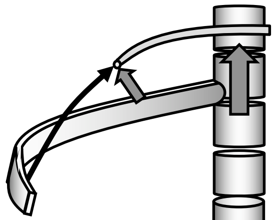




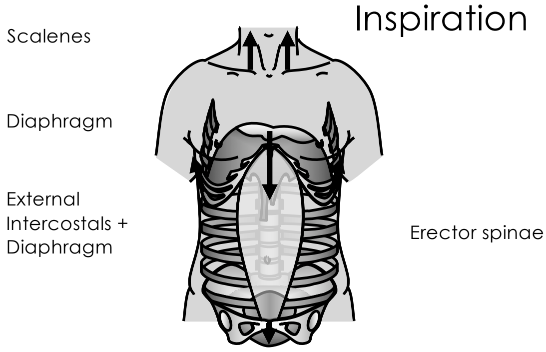




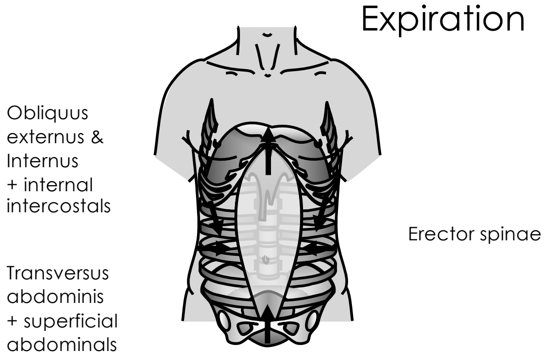




Inspiration

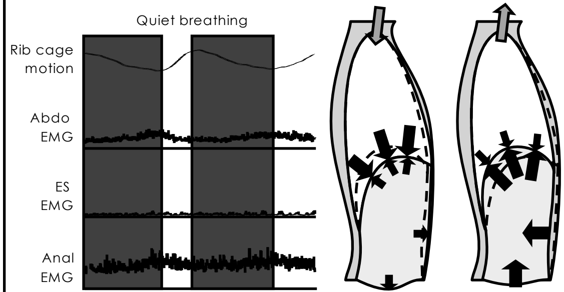


Expiration



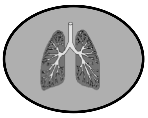
Contribution of the pelvic floor muscles to breathing

Function: Respiration

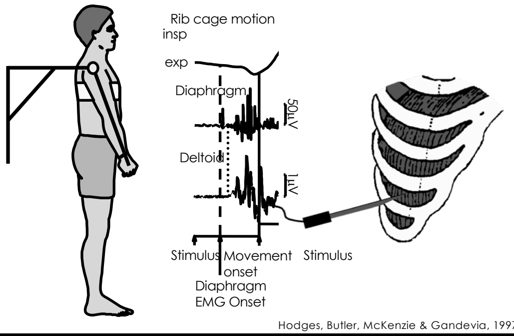


Hodges, Pengel, Sapsford, 2007

Respiratory muscles & lumbopelvic control

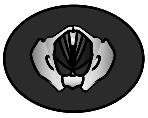


Diaphragm contributes to **predictive** postural control

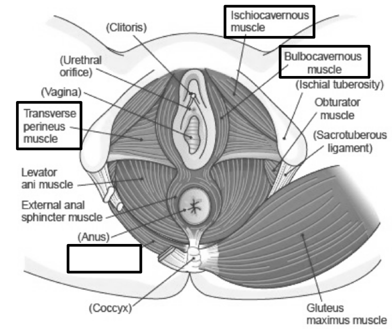


Hodges, Butler, McKenzie & Gandevia, 1997

Continence & pelvic organ support

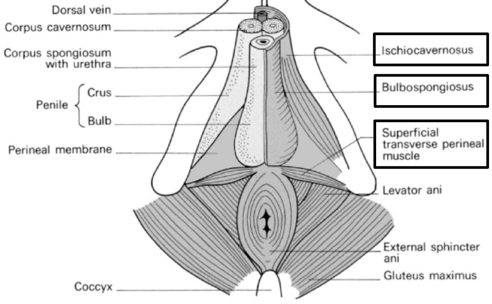


Superficial muscle layer: Female



♀

Superficial muscle layer: Male



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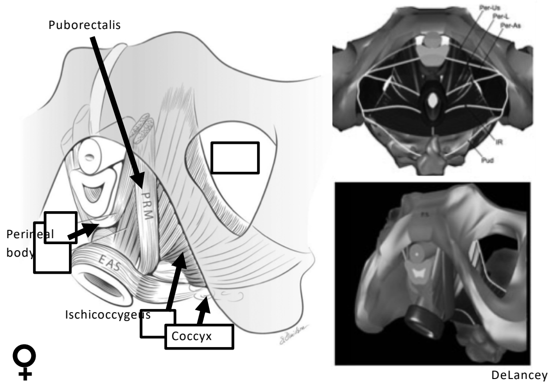
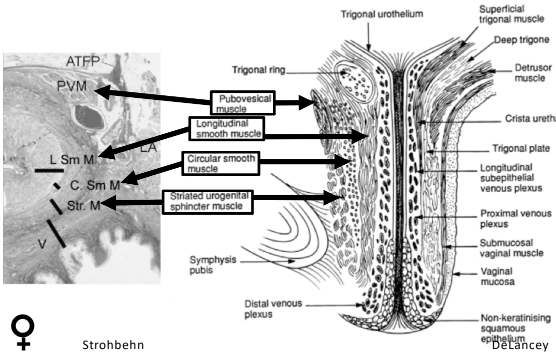


♀

DeLancey

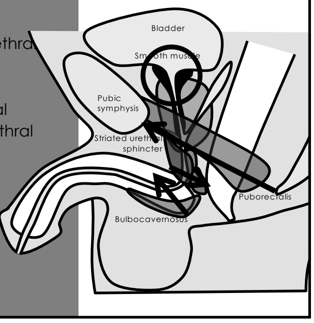
Peri-urethral muscle: Female



♀ Strohbehn DeLancey

Levator ani & urethral muscle: Male

- Pelvic floor muscles
  - **Smooth muscle sphincter** (Lissosphincter, internal urethral sphincter)
  - **Striated urethral sphincter** (Rhabdosphincter, external urethral sphincter, peri-urethral striated muscle)
  - **Levator ani** (Puborectalis, pubovisceralis, pubococcygeus)
  - **Bulbocavernosus**
  - **Urethral mucosa**



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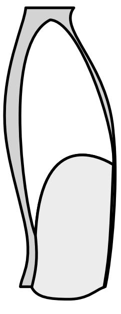
Actions of pelvic floor muscles

- Pelvic organ support
- Urethral anal/rectal pressure
- Intra-abdominal pressure generation
- Sacroiliac forces

→ Control of pressures



Function: Urinary continence

URETHRAL PRESSURE > BLADDER PRESSURE

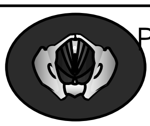
Smooth muscle and elastic mechanisms

Striated levator ani muscles
- Compress distal urethra against pubis
- Stabilise the bladder neck
- Rigid surface against which IAP can compress the urethra

Striated periurethral muscle

Detrusor (Bladder smooth muscle)

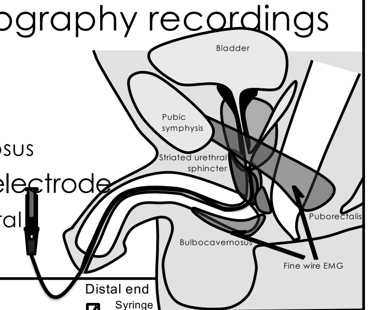
Muscles of the abdominal cavity
- Abdominal muscles
- Diaphragm

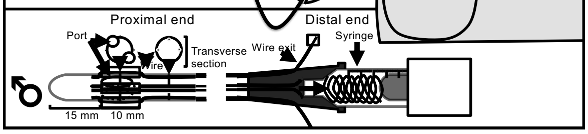


Pelvic floor muscles and lumbopelvic control

Electromyography recordings

- Fine-wire EMG
  - Puborectalis
  - Bulbocavernosus
- Transurethral electrode
  - Striated urethral sphincter





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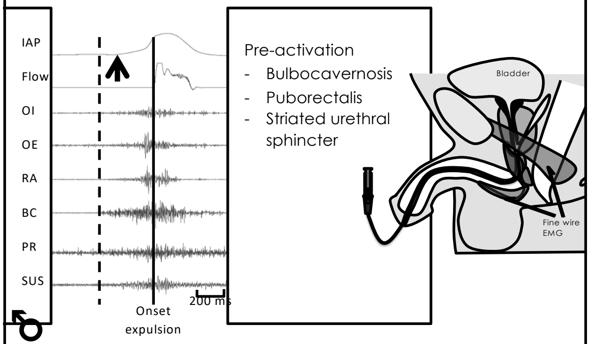
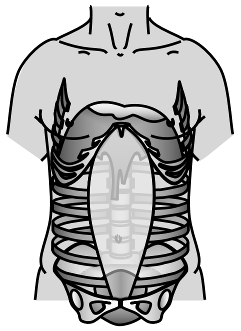
Evoked cough: Pelvic floor muscle EMG



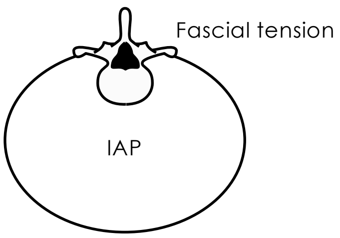
Stafford & Hodges (2014), unpublished data

Function: Postural control

- Intra-abdominal pressure essential for spine control
  - Pelvic floor muscle activation
    - Maintain continence when IAP increases
    - Enable IAP to increase

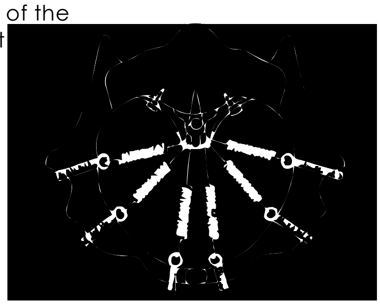


Pelvic floor muscles assist generation of IAP and fascial tensioning

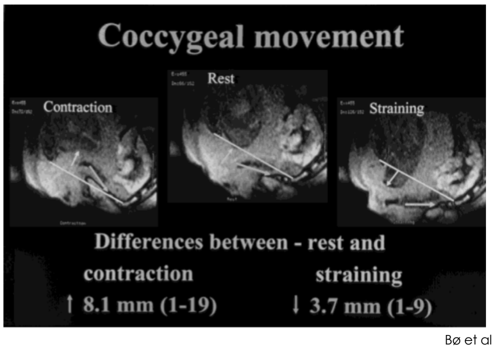


Pelvic floor muscles and trunk control

PFM ↑ stiffness of the sacroiliac joint women



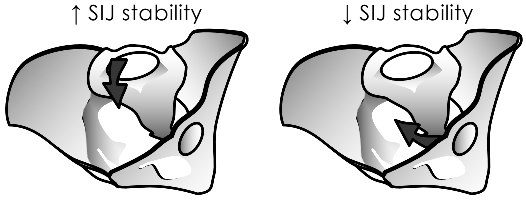
Pool-Goudzwaard et al 2004



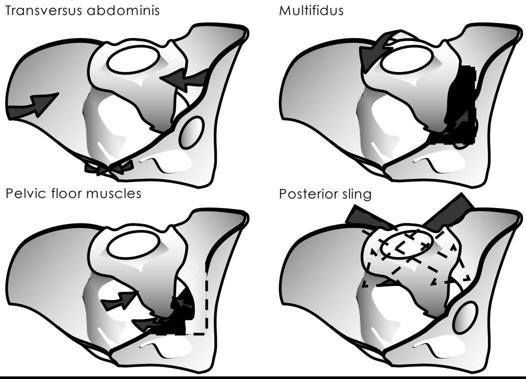
Bø et al, 2001

Sacral nutation

Nutation	Counternutation
↑ SIJ stability	↓ SIJ stability



Force closure of the SIJ



- **Reactive**
  - Feedback loops – simple (fast); complex (slow)
- **Predictive**
  - Feedforward control – based on experience
- **Prepared**
  - Modulation of intrinsic properties – inc. muscle stiffness/tone – ongoing

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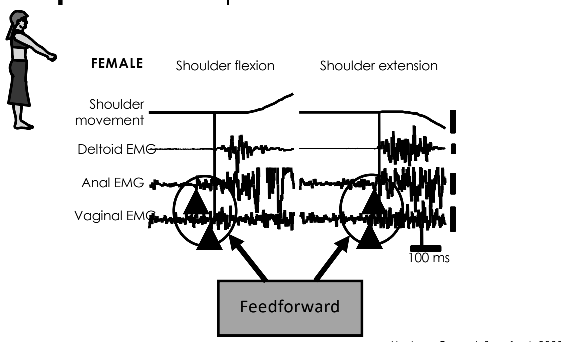
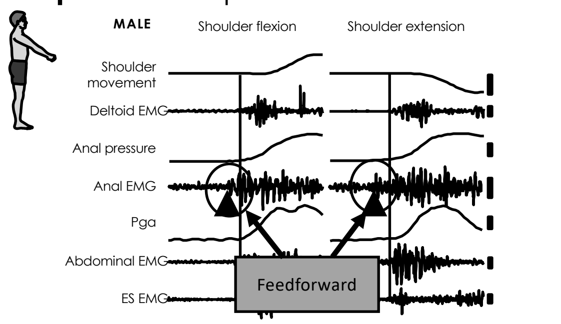
Pelvic floor muscles contribute to **predictive** postural control



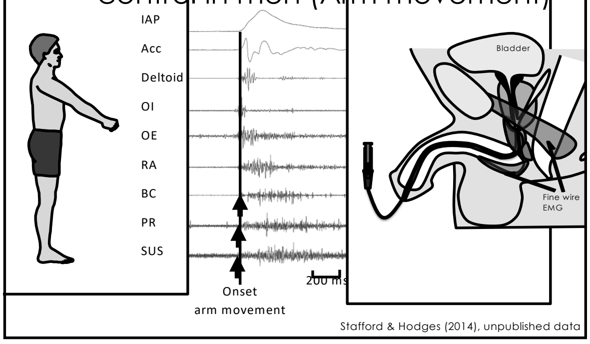
Hodges, Pengel, Sapsford, 2002

Pelvic floor muscles contribute to **predictive** postural control



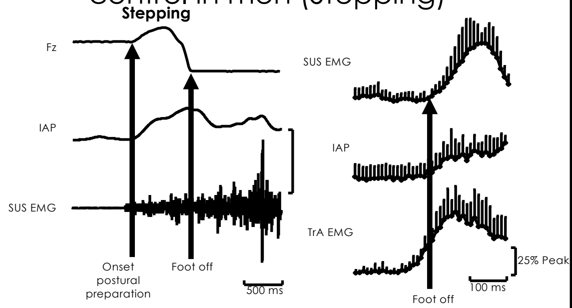
Hodges, Pengel, Sapsford, 2002

Multiple pelvic floor muscles contribute to **predictive** postural control in men (Arm movement)



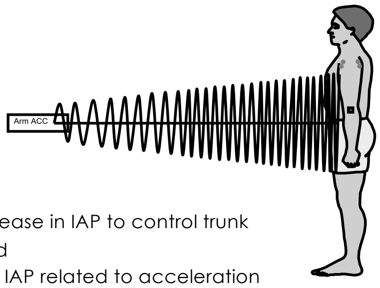
Stafford & Hodges (2014), unpublished data

Multiple pelvic floor muscles contribute to **predictive** postural control in men (Stepping)



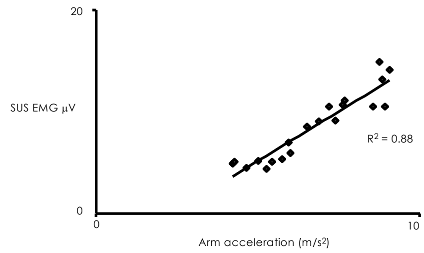
Stafford, Ashton Miller, Sapsford, Hodges, 2012, *Neurourol Urodyn*

Repetitive arm movement

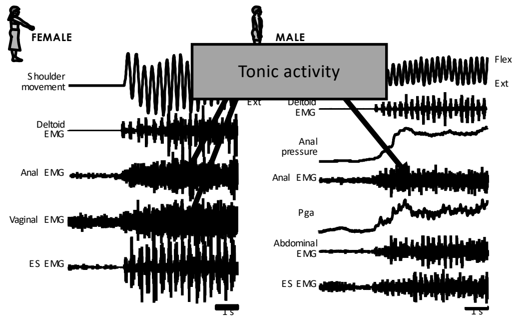


- Transient increase in IAP to control trunk
- Vary demand
- Amplitude of IAP related to acceleration

Repetitive arm movement

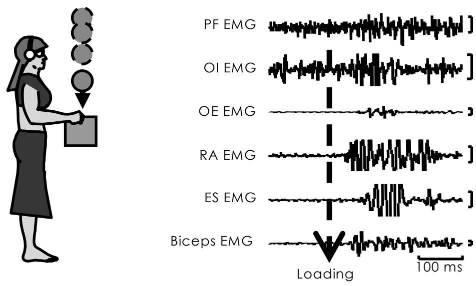


Pelvic floor muscles - **prepared**



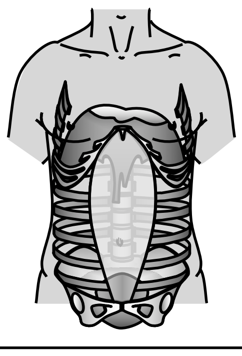
Hodges, Pengel, Sapsford, 2002

Pelvic floor muscles contribute to **reactive** postural control



Smith, Coppieters & Hodges, 2007 *Exp Brain Res*

"Abdominal canister"



- Synergy
  - Coordination between muscles of the abdominal cavity

2 ways to consider interaction between pelvic floor and abdominal muscles

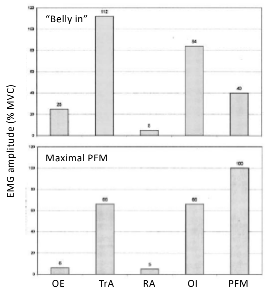
- Positive
  - Collaboration
    - Optimal control
- Negative
  - Opposition
    - Excessive abdominal muscle activity – increase demand for continence

Activation of pelvic floor recruits deep abdominal muscles

- Co-activation during voluntary tasks
  - Sapsford, Hodges, Richardson et al. 2001
- Co-activation with pelvic afferent stimulation
  - Yamamoto et al, 1961
- Neural networks exist to coordinate
  - Holstege et al 2003

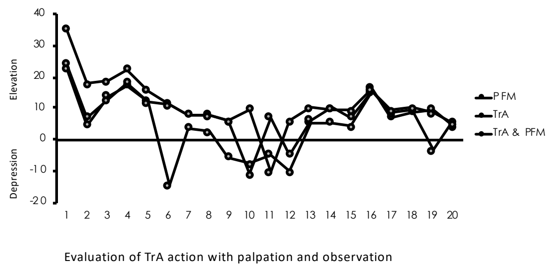
Sapsford et al. (2001) Neurourol Urodyn 20:31-42

Interaction between abdominal & pelvic floor muscles



Neumann & Gill (2002) Int Urogynecol J 13:125–132

Ultrasound imaging: PFM motion



Bo et al (2003) Neurourol Urodynam 22:582-588

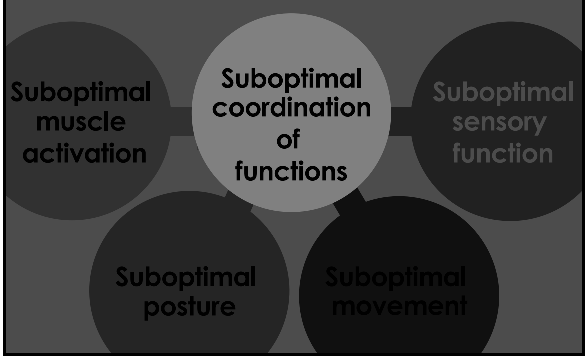
COORDINATION OF SYSTEM

- Abdominal & pelvic floor muscle interaction
  - Sapsford, Hodges et al. 2001
  - Neumann and Gill 2002
  - Critchley et al. 2002
  - Bo, Sherburn, et al. 2003
  - Madill & McLean 2006
  - Thompson, O'Sullivan et al. 2006
  - Junginger et al. 2009
  - Arab & Chehrehrazi 2010
  - Jones & Constantinou 2010
  - Others…

Outline

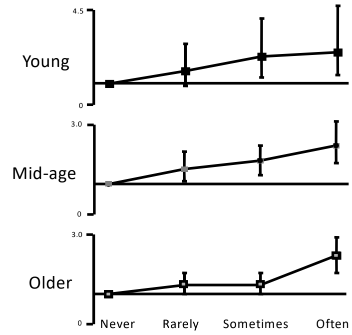
Dysfunction of multiple functions of pelvic & trunk muscles

Coordination of functions



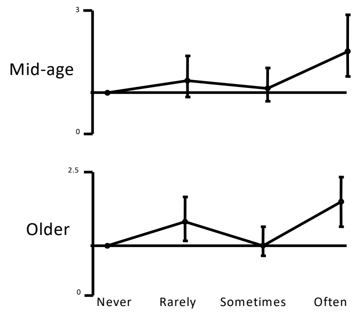
Are **incontinence, respiratory disease,** and **low back pain** related?

Incontinence & back pain



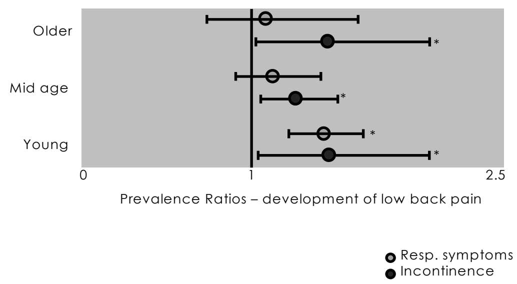
Smith, Russell, Hodges (2005) *J Physiother*

Respiratory disorders & low back pain

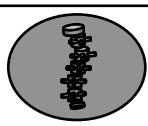


Smith, Russell, Hodges (2005) *J Physiother*

Do **incontinence** & **respiratory disease** increase **risk** for low back pain?

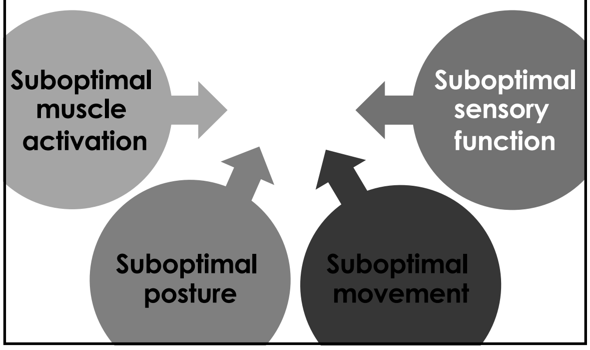


Smith, Russell, Hodges, (2009) *J Pain*

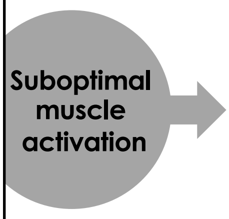


Lumbopelvic pain/ dysfunction

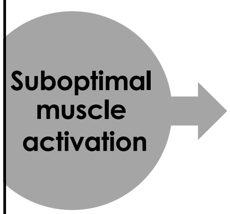
Motor control and LBP



Motor control and LBP



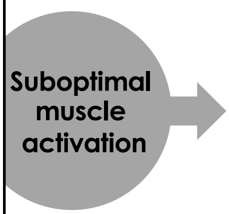
Suboptimal loading of the spine



COMPROMISED MUSCLE
– too little, too late

- Decreased, delayed activation Hodges et al. 1996; Ferreira et al., 2001
- Abnormal motion Cholewicki et al. 1995
- Poor coordination translation/rotation Schneider et al. 2005
- Excessive motion Panjabi, 1992

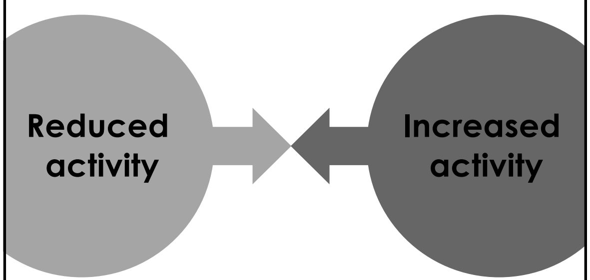
Suboptimal loading of the spine



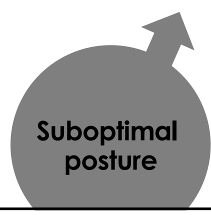
AUGMENTED MUSCLE
– too much, too early, too long

- Co-contraction - ↑ load Marras et al 2007
- ↓ motion - ↓ shock absorption Mok et al 2010
- ↓ variation - ↓ load sharing Moseley & Hodges, 2004

Motor control and LBP

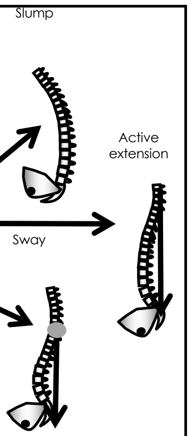


Motor control and LBP

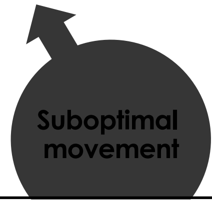


Posture/alignment

- Sup-optimal loading
  - Sustained end range posture (entire spine or region)
  - Excessive muscle activity
  - Compromised muscle activity
  - Subgroups – e.g. flexion, extension (active/passive) (Dankaert et al., 2008)



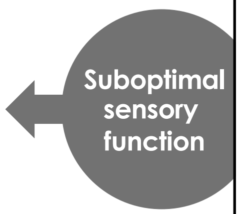
Motor control and LBP



Movement

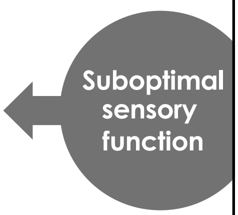
- Sub-optimal loading
  - Decreased movement or movement variability (Mok et al. 2008)
  - Too much movement
    - Provocative movement pattern
    - Imprecise movement pattern (e.g. accessory motions) (van Dillen et al, 2009)

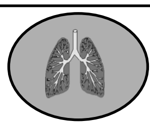
Motor control and LBP



Suboptimal loading of the spine

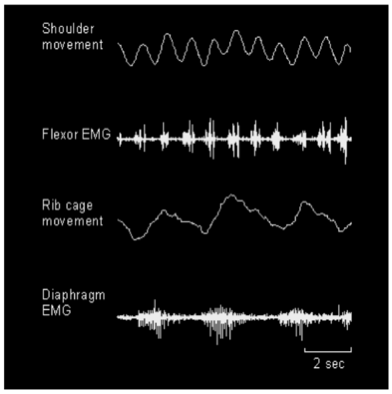
- Inacurate input
  Panjabi 2006
- Inaccurate use of input
  Brumagne et al. 2004
- Inaccurate central representation and integration of input
  Flor et al. 1997
  Luomajoki & Moseley 2011





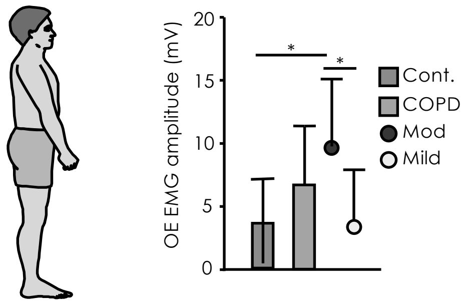
Breathing disorders

Is postural function of the respiratory muscles disrupted in respiratory disease?



Hodges, Heijnen & Gandevia, 2001b

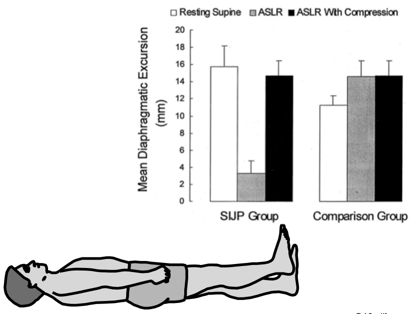
Muscle activation & breathing



Smith, Coppieters, Hodges, submitted

Is respiratory muscles function disrupted in low back and pelvic pain?

Lumbopelvic pain & diaphragm function



O'Sullivan et al, 2002 Spine 27:E1-8

Urinary incontinence/pelvic floor muscle dysfunction

Dysfunction

- Continence
- Obstructive disorders
- Pelvic organ support
- Postural control
- Pelvic pain disorders

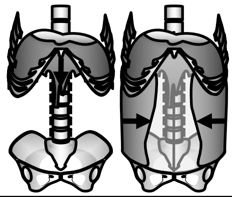
Dysfunction of pelvic floor muscles
- Insufficient pelvic floor muscle activation
- Weakness
- Excessive activation
- Pelvic floor trauma/injury
- Prostatectomy

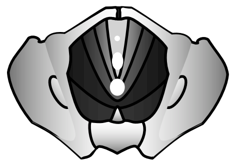
Role of other mechanisms
- Insufficient passive support
- Excessive intra-abdominal pressure – abdominal & diaphragm muscles

Continence is challenged by multiple factors

Diaphragm & abdominal muscle
- Inc. IAP/bladder pressure
- Levator plate descent
- Limited inc. urethral pressure

Pelvic floor muscles
- Inc. urethral pressure
- Levator plate elevation

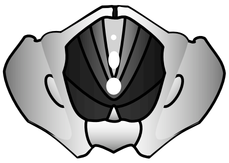




Pelvic floor muscles and incontinence

Stress Urinary Incontinence

Bladder pressure
>
Urethral pressure



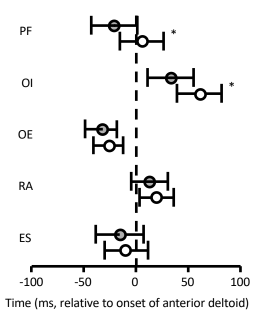
Hypermobility of bladder neck

↓ PFM strength & endurance
e.g. Morkved et al 2004; Deindl et al 1994

Deficits in PFM activity (amplitude +/- timing)
e.g. Delancey et al 1994; Devreese et al 2004

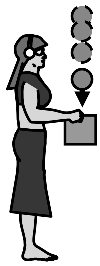
Inc. dorsal motion anorectal angle
Jones et al 2010

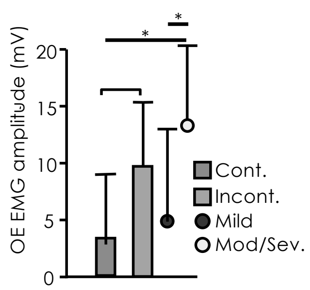
Is postural function of muscles of continence changed in stress urinary incontinence



Smith, Coppieters, Hodges, 2008

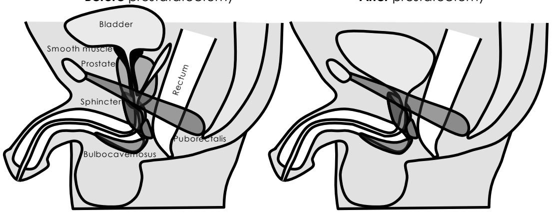
Augmented obliquus externus abd. activity in stress urinary incontinence





Smith, Coppieters, Hodges, (2008) Neurourol Urodyn

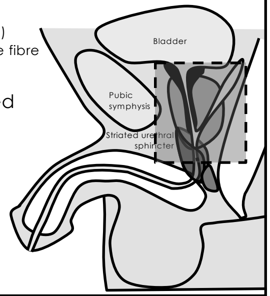
Impact of radical prostatectomy



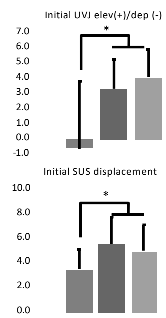
- Removal of prostatic urethra including smooth muscle
- Interference with bladder neck
- +/- Striated urethral sphincter injury
- Exposure/irritation of bladder
- Lower bladder position

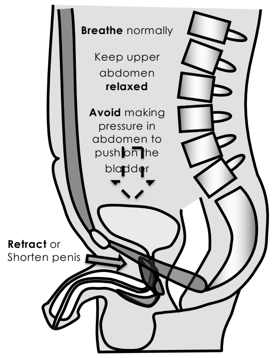
Recovery of continence after radical prostatectomy

- Compensate for reduced **smooth muscle** contribution to continence
  - → Striated muscles change function
  - → Enhanced tonic activation (neural?)
  - → Enhanced muscle capacity (muscle fibre change?)
- Compensate for compromised **striated urethral sphincter**
  - → Greater reliance on puborectalis & bulbocavernosus
- Restore **bladder** function
  - → Train bladder storage



Clinical implications

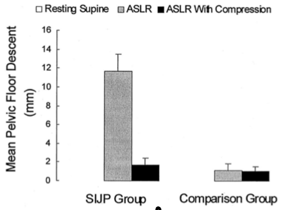


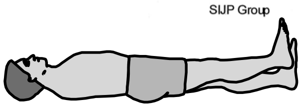


Conclusion

- Differences in activation of individual PFM in men with persistent incontinence after prostatectomy
- Early evidence of subgroups
- Potential to target treatment

Lumbopelvic pain & pelvic floor muscle function

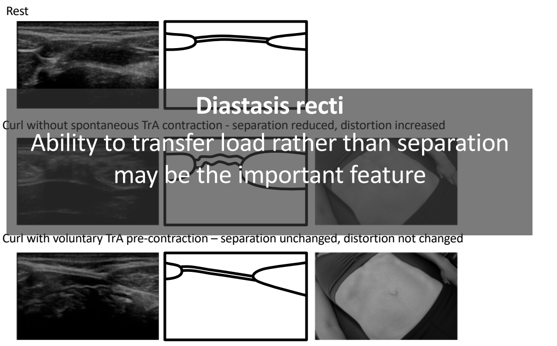




O'Sullivan et al, 2002 Spine 27:E1-8

Diastasis rectus abdominis

Load transfer & fascia



Diastasis recti

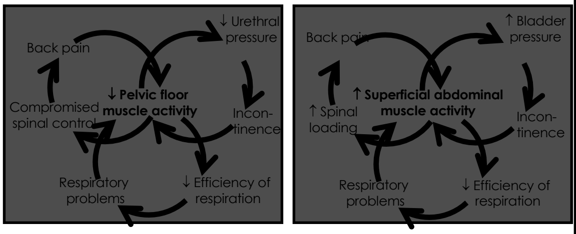
Ability to transfer load rather than separation may be the important feature

Lee & Hodges (2016) JOSPT

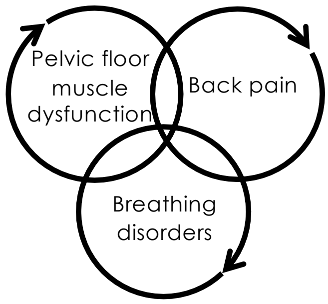
Outline

Implications for rehabilitation

Hypothesised physiological association



Pelvic floor muscle dysfunction, breathing disorders & back pain



Key messages

- Spine control requires balance between movement and stiffness
- Coordination of complex muscle system
- Involves a range of neural mechanisms
- Trunk muscles can be coordinated to meet diverse functional goals

Key messages

- Motor control is changed in pain
- Motor control is changed in breathing disorders
- Motor control is changed in genitourinary dysfunction
- Individualised training is required to restore optimal control