RIB STRESS FRACTURES IN ELITE ROWERS

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Herlev Hospital, Copenhagen, Denmark & Lund University, Sweden

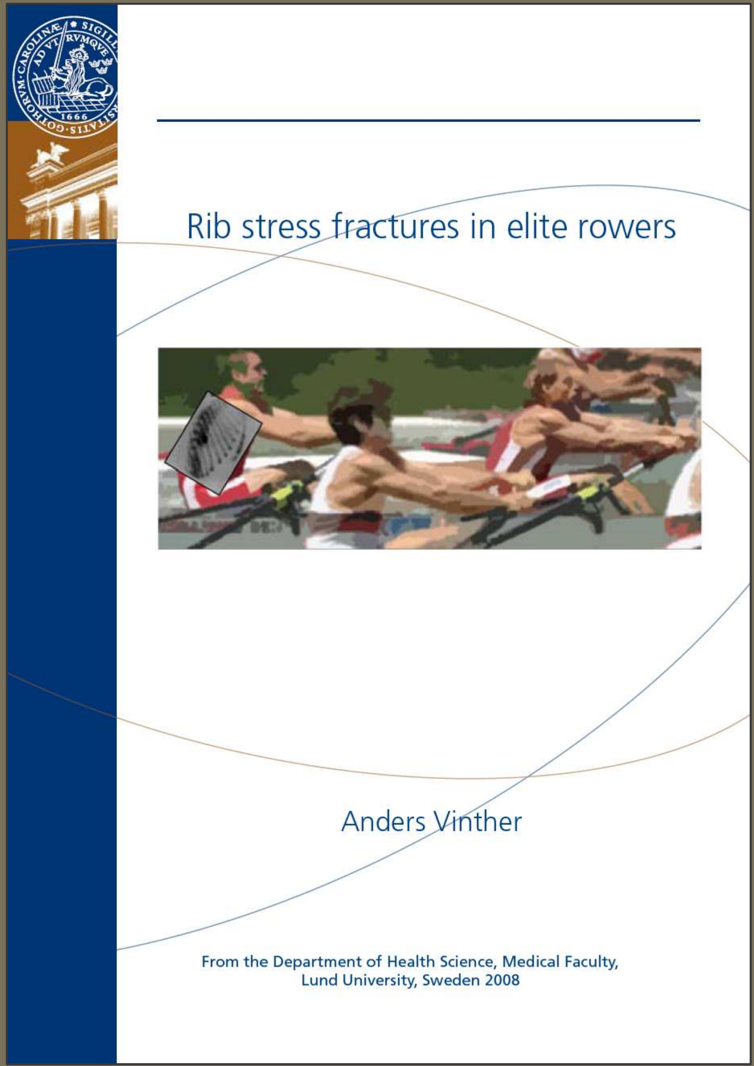
World Rowing Coaches Conference, Copenhagen 2010

RIB STRESS FRACTURES IN ELITE ROWERS

Danish National Rowing Team
Physiotherapist 1999 – 2001

Rib stress fracture research
since 2000

Ph.d. January 2009



RIB STRESS FRACTURES IN ELITE ROWERS

1. Stress fractures in general
   - Definition
   - Pathogenesis
2. Rib stress fractures in elite rowers
   - Epidemiology
   - Suggested risk factors and injury mechanisms
3. Investigations of:
   - Bone Mineral Density (BMD)
   - Muscular co-contraction
   - Muscle strength
   - Rowing technique
   - Testosterone and BMD in male lightweight rowers
   - Biomechanics of slide-based ergometer rowing

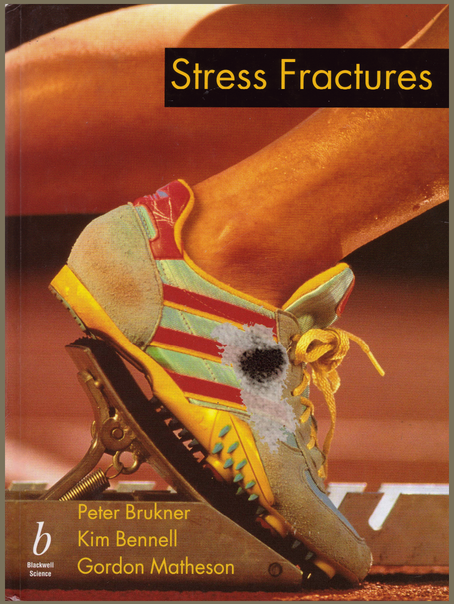
RIB STRESS FRACTURES IN ELITE ROWERS

<u>**Stress fracture:**</u>

Definition:

"A stress fracture can be defined as a partial or complete bone fracture that results from repeated application of stress lower than the stress required in order to fracture the bone in a single loading."

Bone stress is the load or force applied per unit area and results in bone deformation known as bone strain.



Brukner P, Bennell KL, Matheson G
Stress fractures. Australia: Blackwell Science; 1999.

RIB STRESS FRACTURES IN ELITE ROWERS

Stress fracture:

Stress fractures are developed over time when the natural remodeling of bone cannot compensate for (repair) the accumulating microdamage caused by a combination of the repetitiveness of the bone strain, the strain rate, the strain magnitude and the limited periods of recovery allowed between exposure to the bone strain.

Warden SJ, Gutschlag FR, Wajswelner H, Crossley KM. Aetiology of rib stress fractures in rowers.
Sports Med 2002;32:819-836

Figure from:
Brukner P, Bennell KL, Matheson G
Stress fractures. Australia: Blackwell Science; 1999.

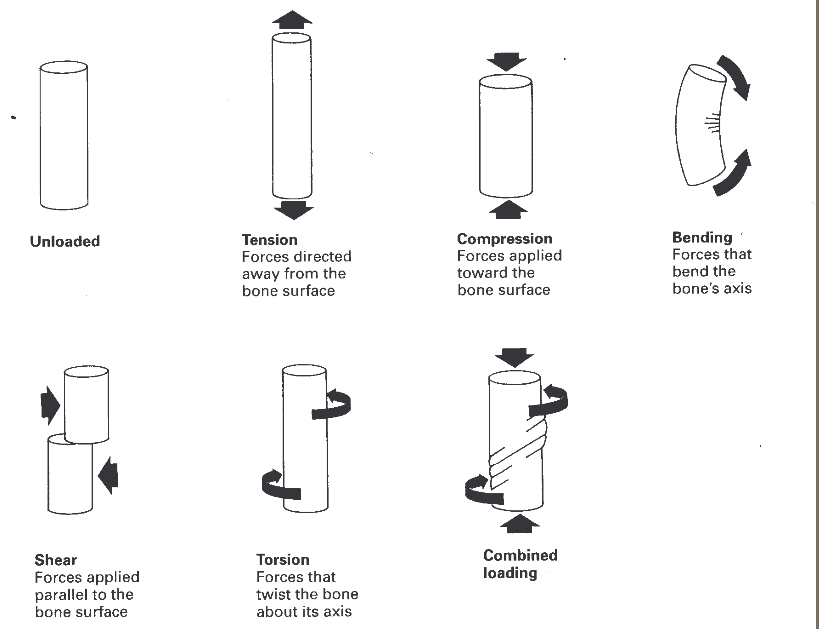


Fig. 1.1
Loading modes. (Adapted and reproduced, with permission, from Nordin M, Frankel VH. *Basic Biomechanics of the Musculoskeletal System.* Philadelphia: Lea & Febiger, 1989: 10.)

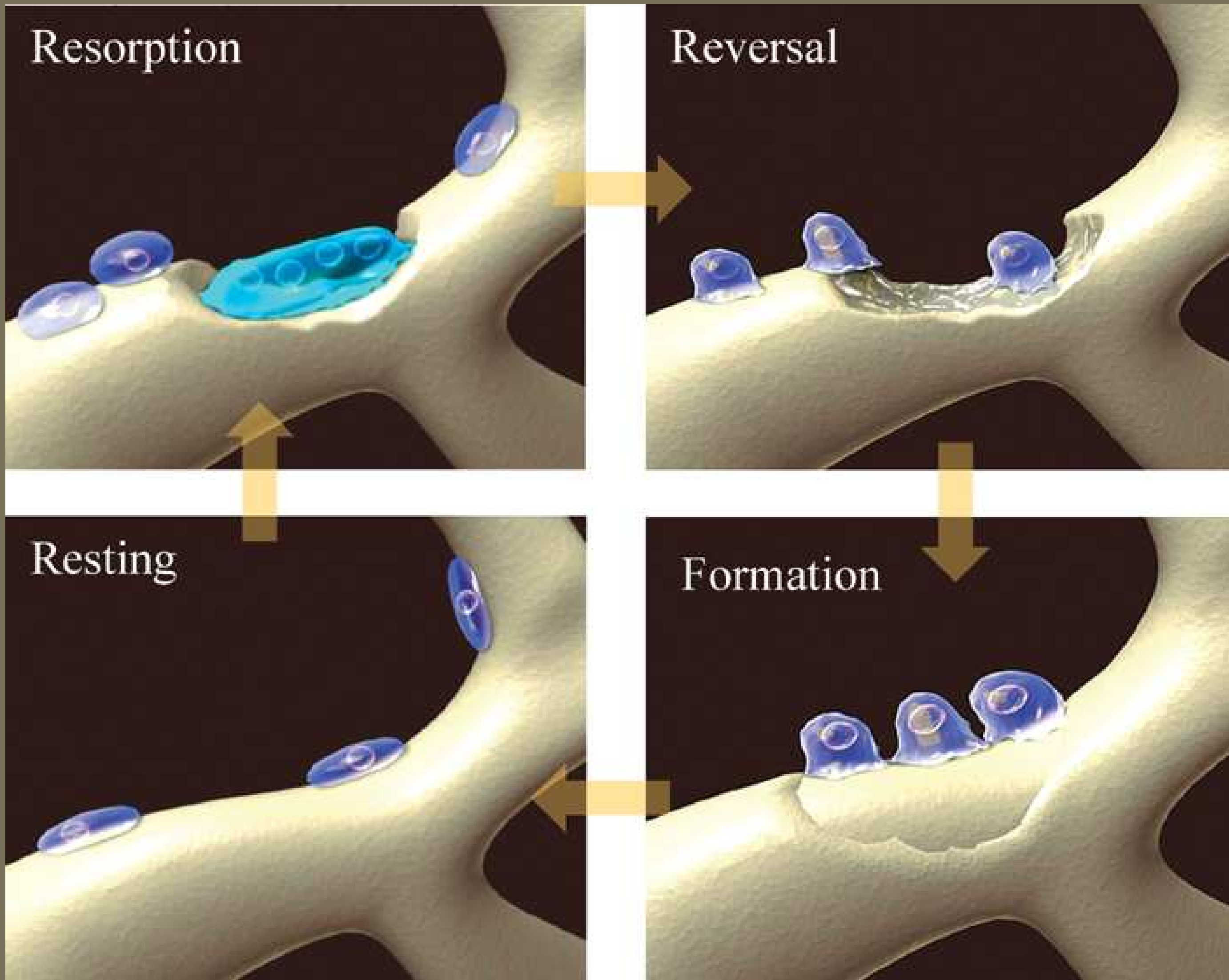
RIB STRESS FRACTURES IN ELITE ROWERS

Continuum of clinical responses to bone loading

Normal remodeling → Accelerated remodeling → Stress reaction → Stress injury → Stress fracture → Complete fracture

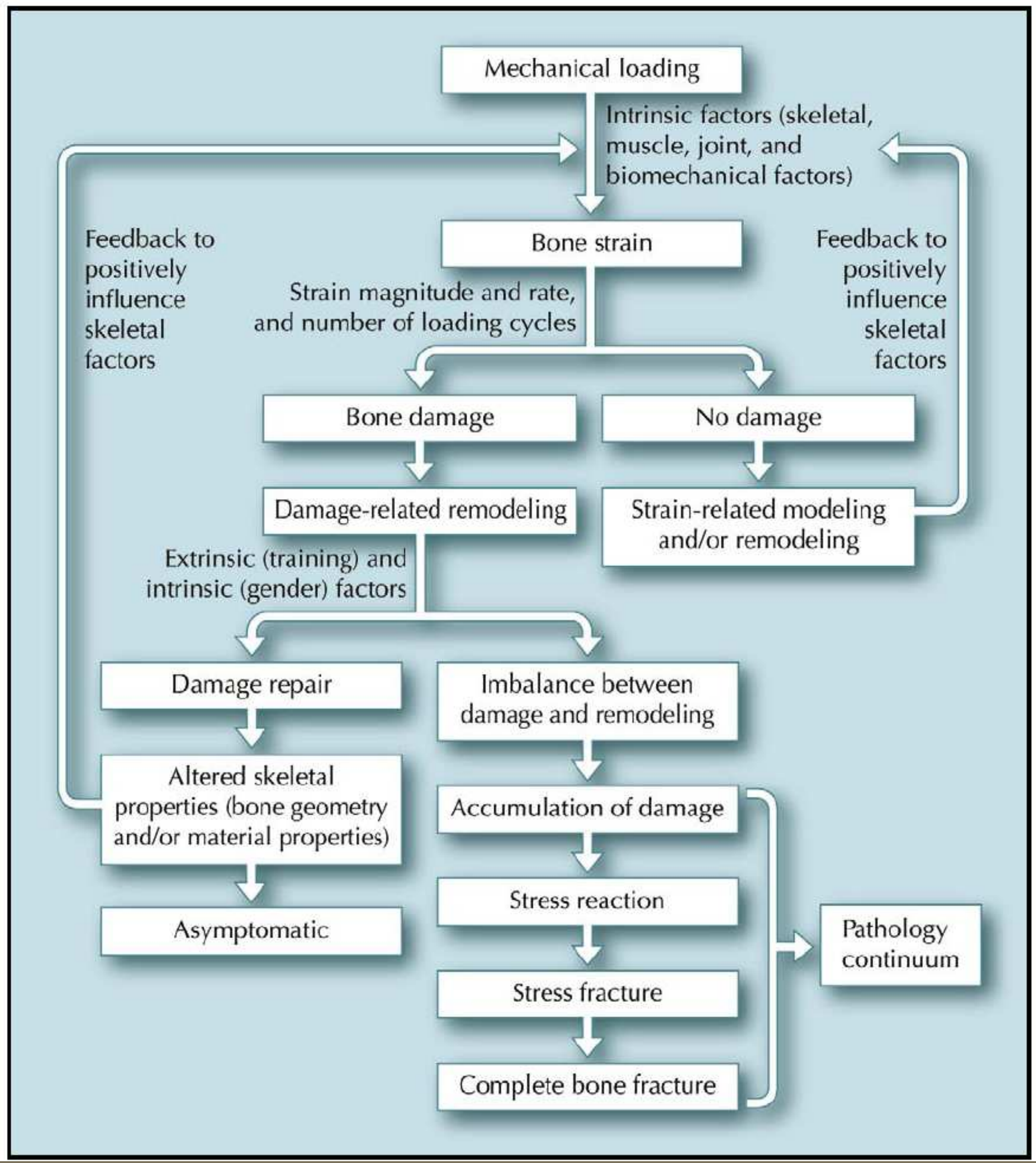
Brukner, Bennell and Matheson, Stress fractures, 1999

RIB STRESS FRACTURES IN ELITE ROWERS



Coxon JP et al. Prostate Cancer Prostatic Dis. 2004;7(2):99-104.

RIB STRESS FRACTURES IN ELITE ROWERS



Current Osteoporosis Reports 2006, **4:**103–109 *Stuart J. Warden, PhD, PT, David B. Burr, PhD, Peter D. Brukner, MBBS*

RIB STRESS FRACTURES IN ELITE ROWERS

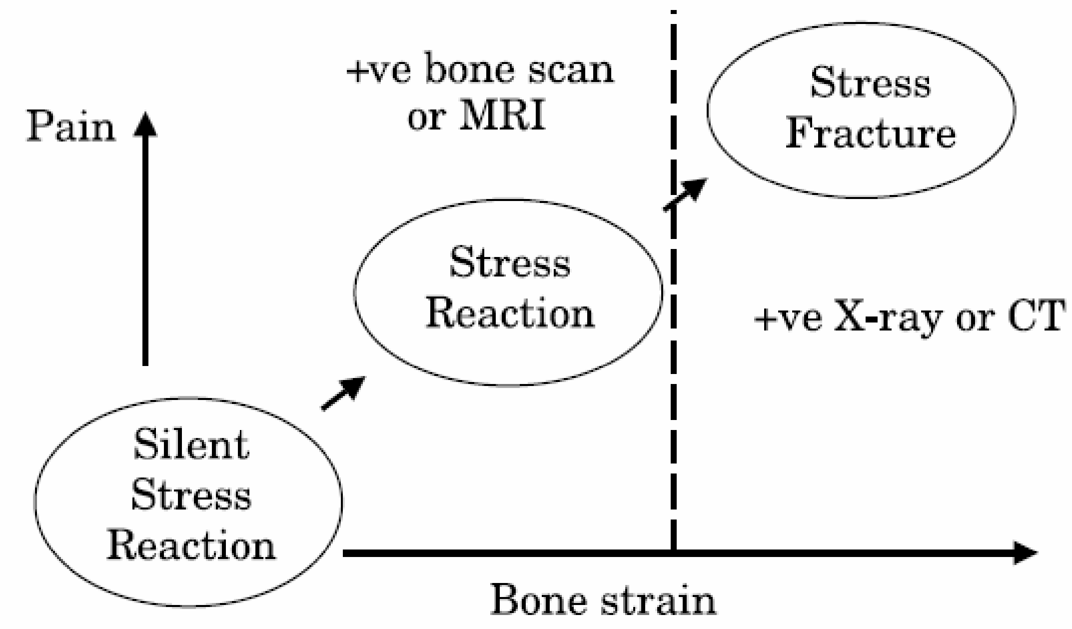


Fig. 3. Relationship between the bone strain continuum and diagnostic findings on bone scan, MRI or CT.

K. Bennelland P. Brukner / Physical Therapy in Sport 6 (2005) 171–180

RIB STRESS FRACTURES IN ELITE ROWERS

Anders Vinther, RPT, Ph.D, Herlev Hospital and Lund University

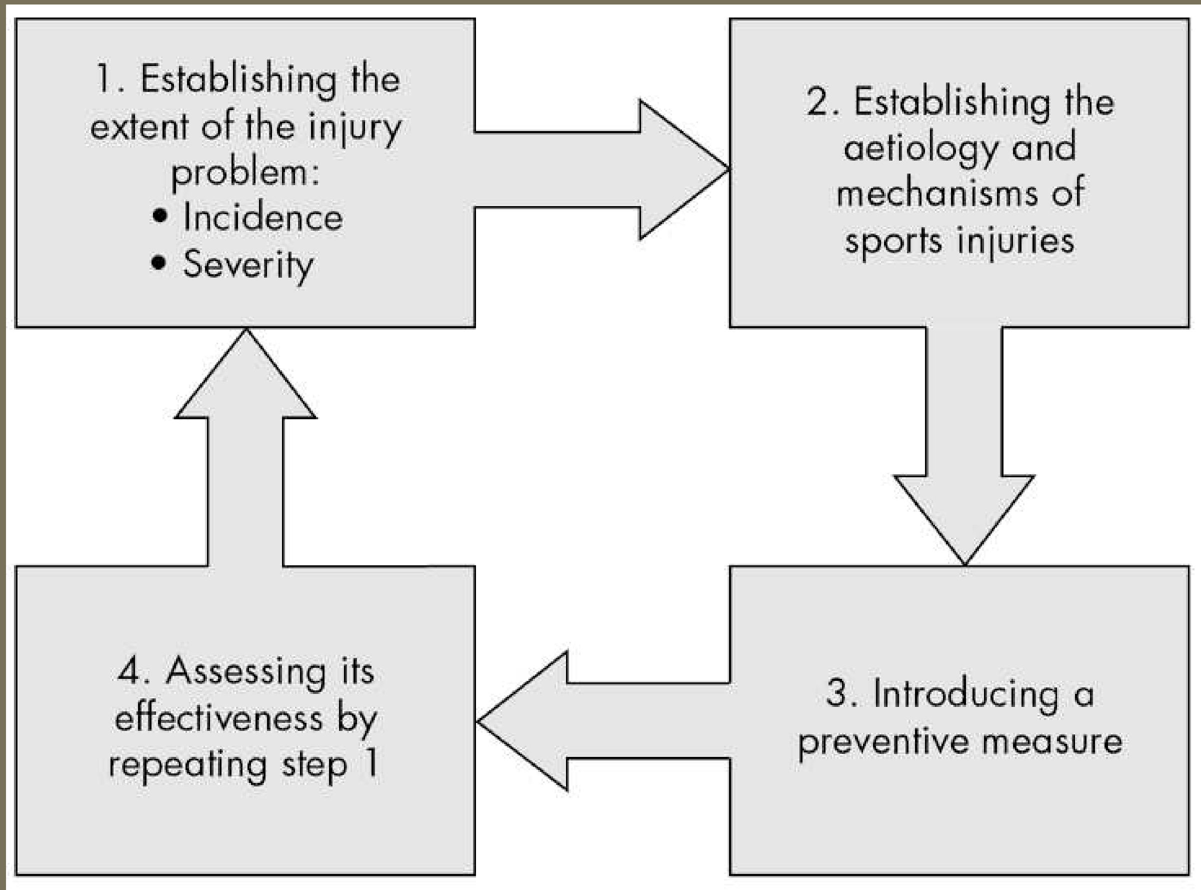
RIB STRESS FRACTURES IN ELITE ROWERS

"The Pathology and prevention of rib stress fractures will be one of the most useful areas of research in rowing injuries."

Budget R, Hettinga D.M, Steinacker J. Sports medicine.

In Secher NH & Volianitis S, Editors. *Rowing*. London: Blackwell; 2007. p. 128

Model for sport injury prevention



van Mechelen et al. 1992

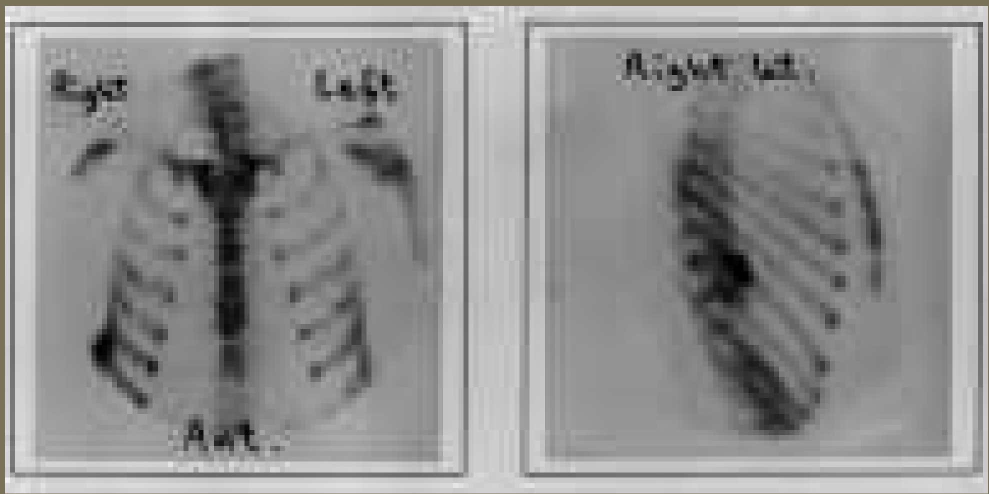
RIB STRESS FRACTURES IN ELITE ROWERS
- Introduction:

Incidence: 6.1 – 12 % (Warden et al. 2002)
Danish national rowing team incidence 2002: 16.7%

Severity: Average time from diagnosis to resumed training: 3-8 weeks
2 Danish rowers missed the 2002 World Championships due to rib stress fractures

Location: Anywhere in the ribs 2 to 10 - 93 % in the ribs 4 to 8 (Warden et al. 2002)

Diagnosis: History, clinical examination and 99m Technetium MDP bone scan



RIB STRESS FRACTURES IN ELITE ROWERS
- Suggested mechanisms of injury and risk factors:

Stress forces induced to the ribs by muscular contractions

Rib cage compression

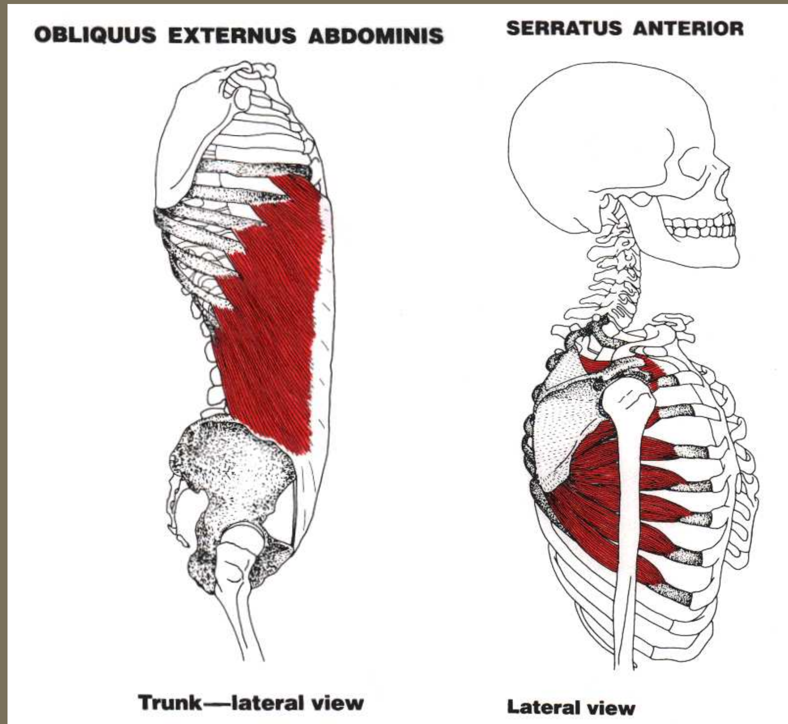
Rowing technique

Changed training routines

Bone mineral density

Bone geometry

Bone remodeling



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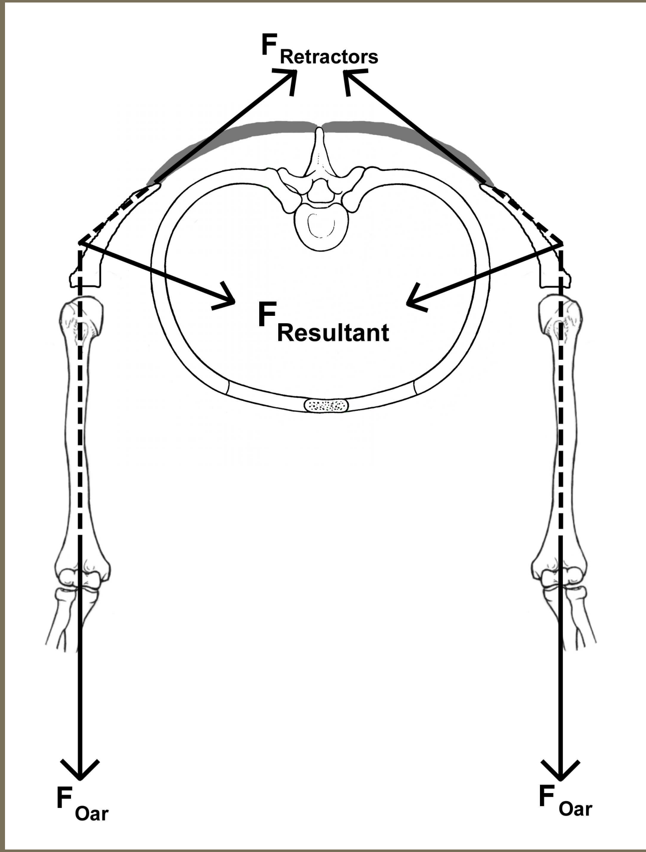

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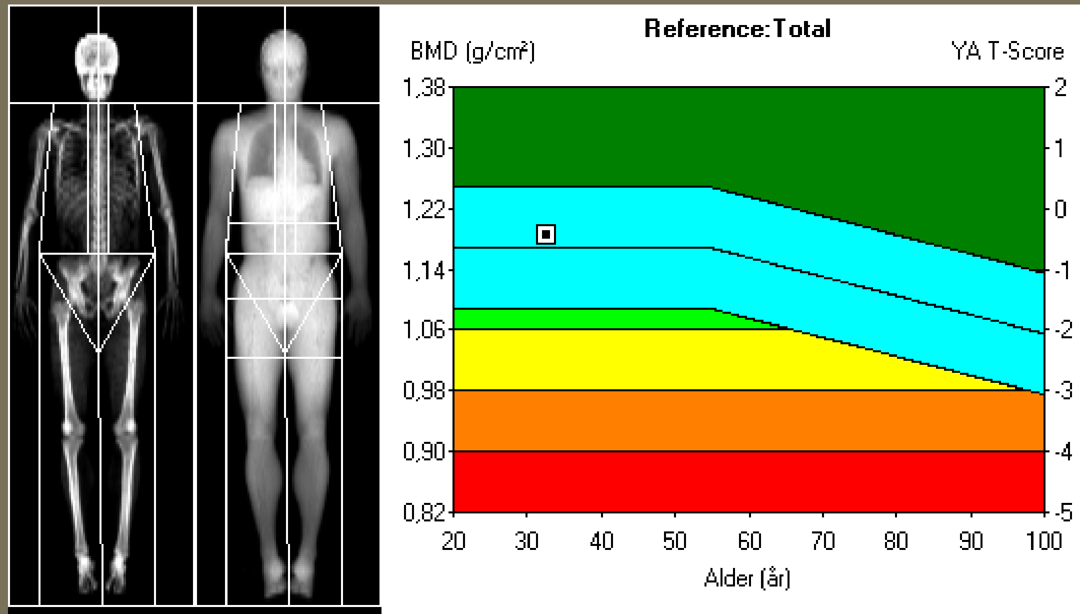

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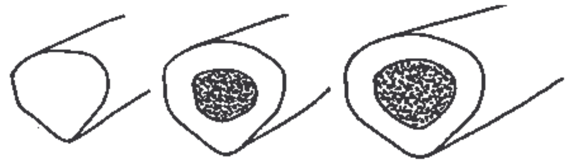

Area (cm^2)	2.77	2.77	2.84
Moment of inertia (cm^4)	.61	1.06	1.54
Bending strength (%)	100%	149%	193%

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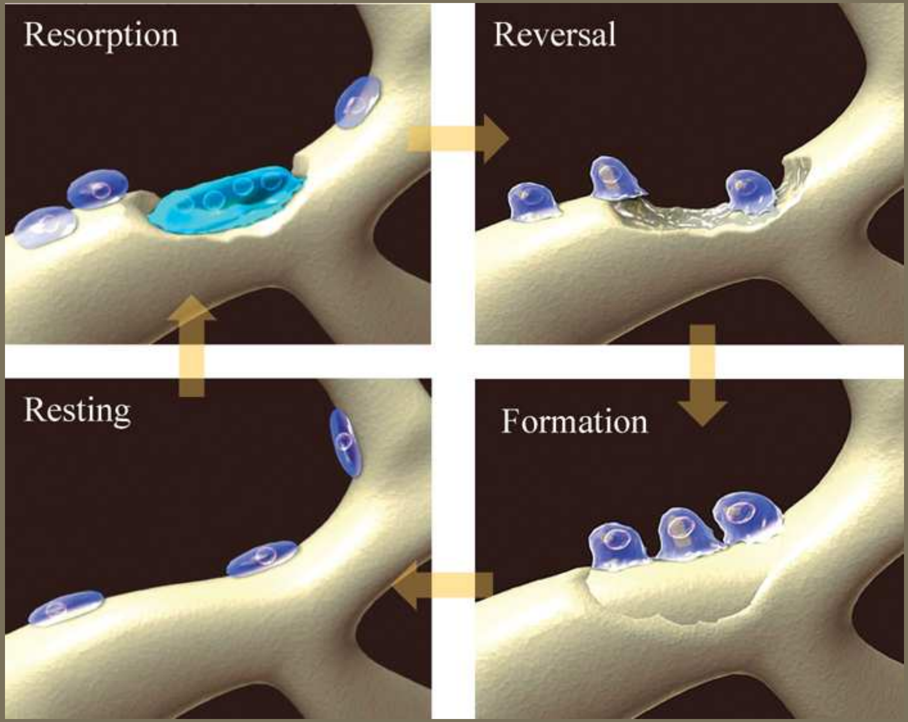


Coxon JP et al. Prostate Cancer Prostatic Dis. 2004;7(2):99-104.

Study 1 & 2

RIB STRESS FRACTURES IN ELITE ROWERS
- Study design:

Material:

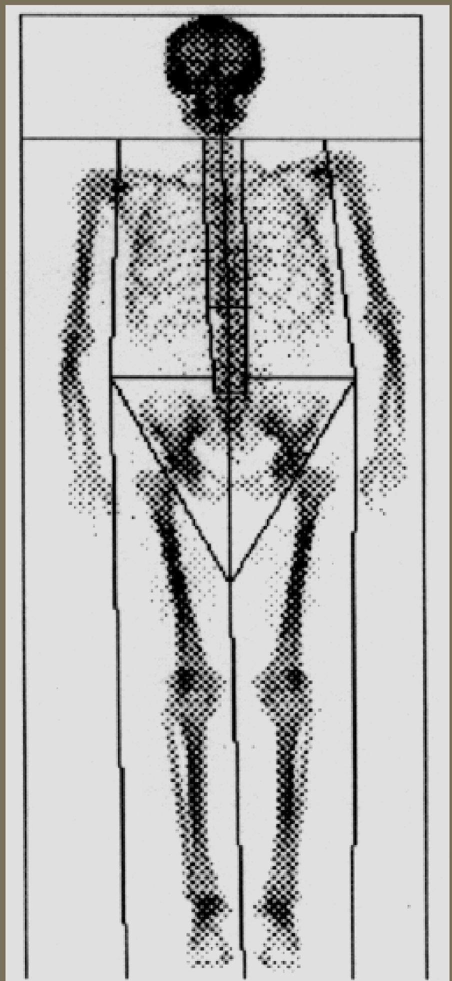
7 Danish national team rowers with previous rib stress fractures and 7 controls matched for gender, age , height, weight and training experience.

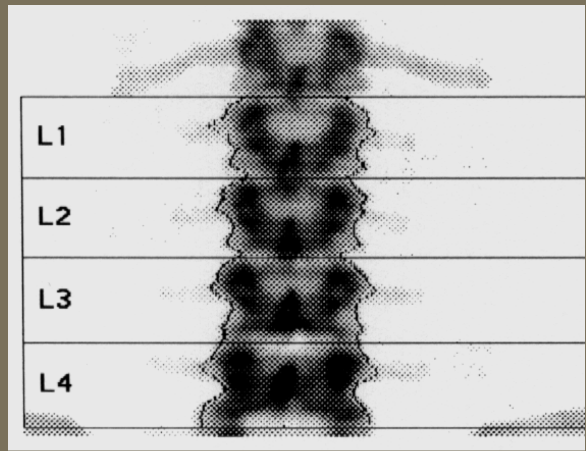
Aim:

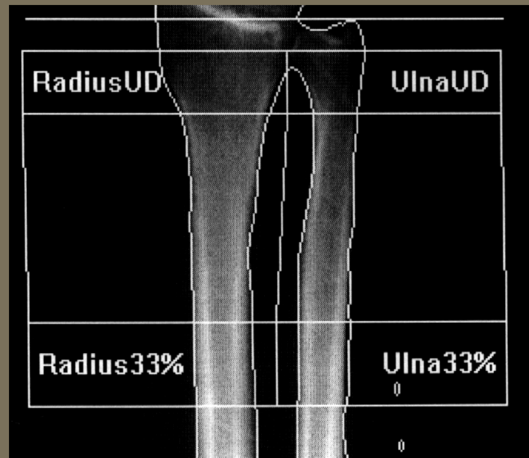
To investigate if the rowers with previous rib stress fractures are different from their matched controls with respect to the following parameters.

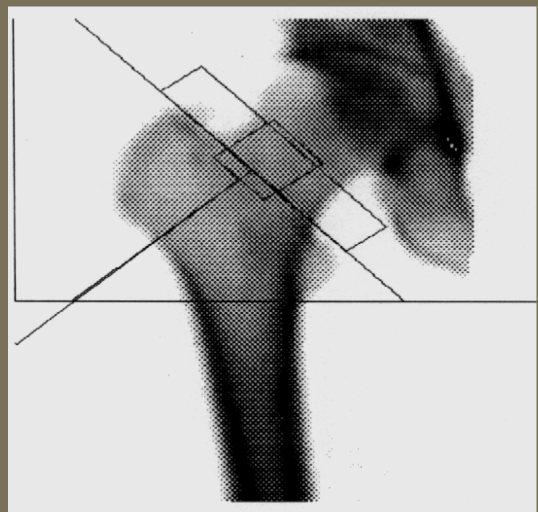
Study 1

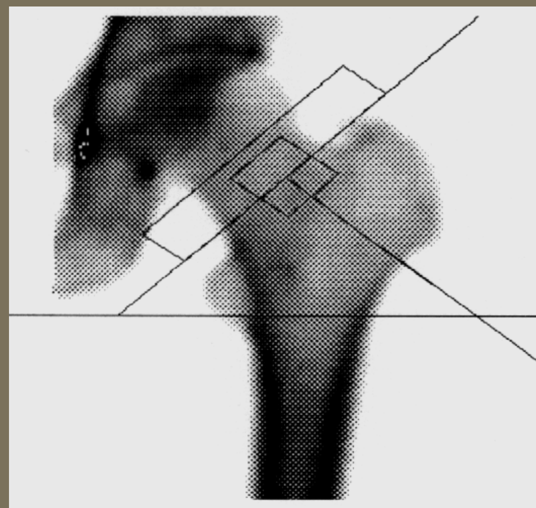
RIB STRESS FRACTURES IN ELITE ROWERS
-Measurements and methods: DEXA scans:





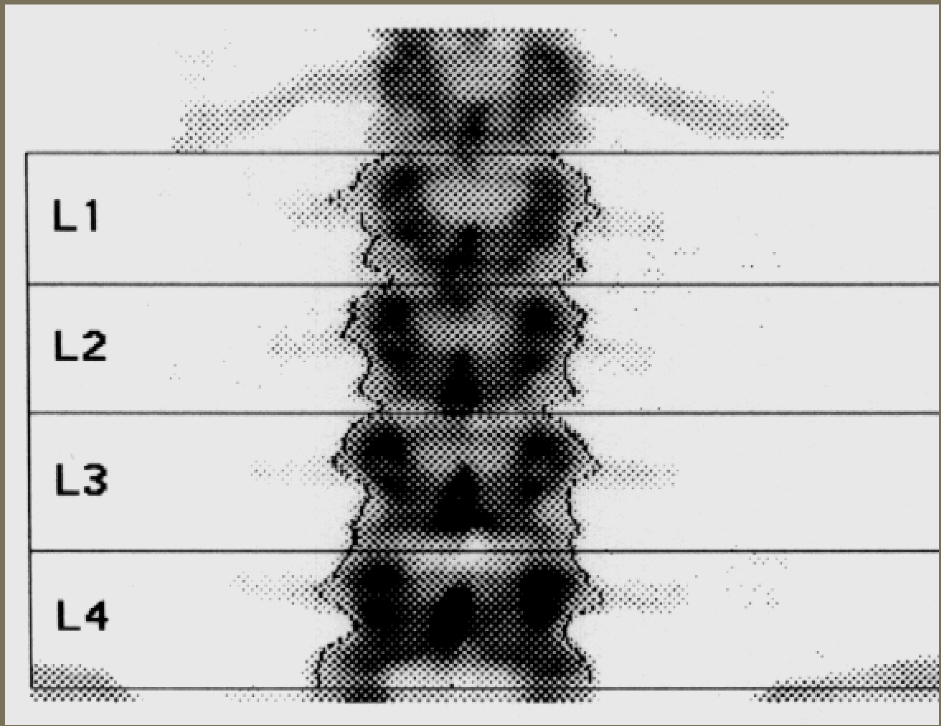






Study 1

RIB STRESS FRACTURES IN ELITE ROWERS
- Results: L2 - L4 BMD



% of normal young adult reference population:

Controls :	115.3	(108 - 127)
RSF :	99.1	(85 - 111)
		($p= 0.028$)

$g \cdot cm^{-2}$:

Controls:	1.40	(1.27 - 1.57)
RSF:	1.22	(1.02 - 1.37)
		($p= 0.028$)

Scand J Med & Sci Sports 2005;15:95-99

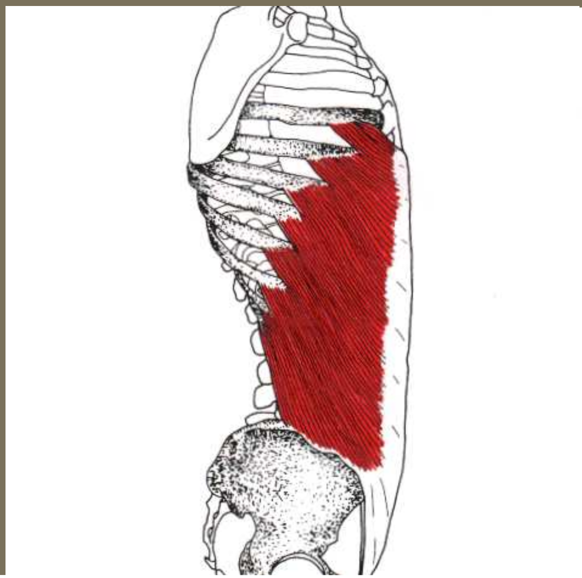
RIB STRESS FRACTURES IN ELITE ROWERS
- Measurements and methods:

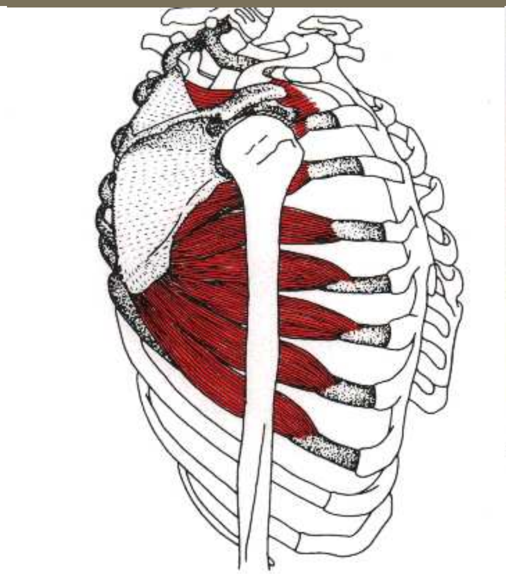
Study 2

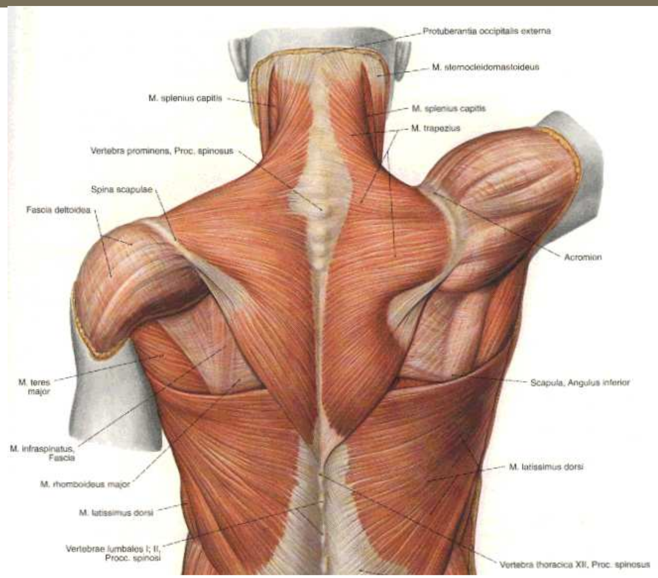
Neuromuscular activity and magnitude of co-activation of serratus anterior, obliquus externus abdominis and trapezius middle and lower fibers during the rowing stroke.

Method:

EMG-analysis during high intensity ergometer rowing.

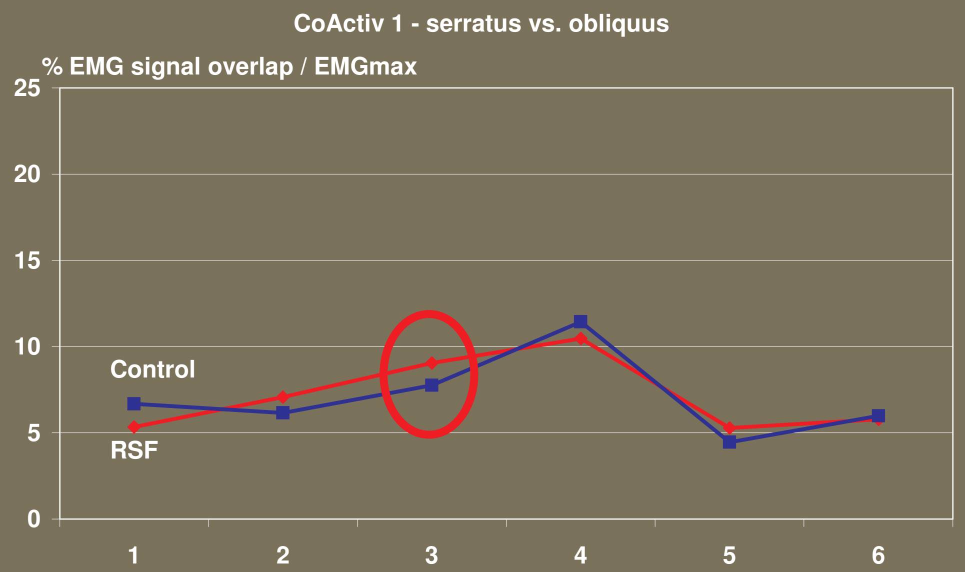


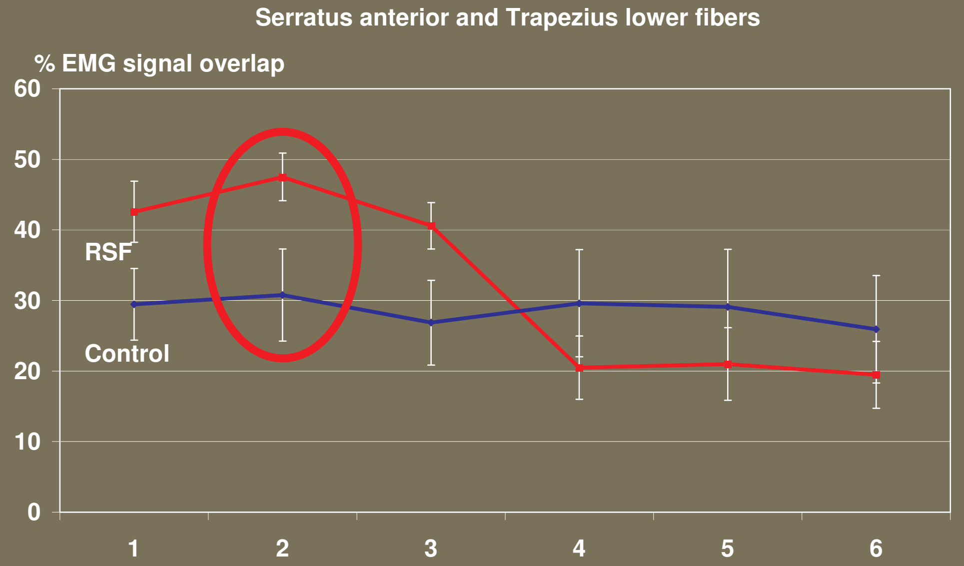




Study 2

RIB STRESS FRACTURES IN ELITE ROWERS -Results: EMG





Scand J Med Sci Sports. 2006;16:188-196

Study 2

RIB STRESS FRACTURES IN ELITE ROWERS - Measurements and methods:

Velocity of the seat and the handle during the rowing stroke.

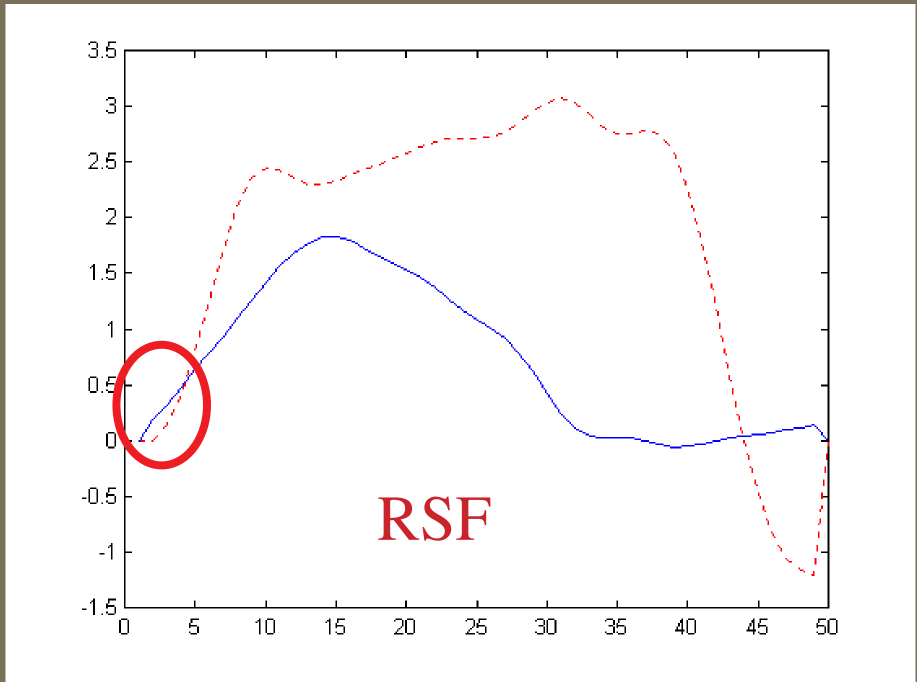
Shoulder flexion angle during the rowing stroke.

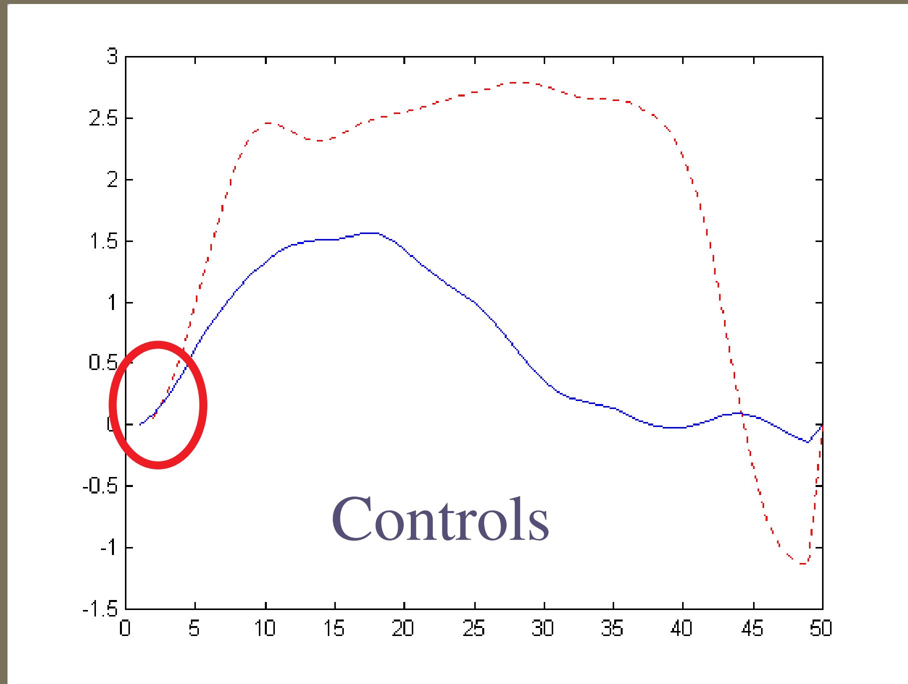
Method:

2-D video analysis.

Study 2

RIB STRESS FRACTURES IN ELITE ROWERS - Results: 2-D video analysis





Velocity of the seat (blue) and handle (red)

Average seat velocity first 0 0.6 sec: RSF: 0.25 ms $^{-1}$ Controls: 0.15 ms $^{-1}$ ($p<0.05$)

Seat-handle-difference first 0 0.6 sec: RSF: 0.18 ms $^{-1}$ Controls: -0.01 ms $^{-1}$ ($p<0.075$)

Scand J Med Sci Sports. 2006;16:188-196

Study 2

RIB STRESS FRACTURES IN ELITE ROWERS
- Measurements and methods:

Elbow flexion strength relative to knee extension strength.

Method:

Biodex - isokinetic muscle strength - angle velocity: 30°/sec

RIB STRESS FRACTURES IN ELITE ROWERS - Results: BIODEX

Study 2

-Force presented as Nm and ratio calculated as knee-ext./elbow-flex.:

- **Controls (n=7):**
- **Elbow-flexion: 57.87 Nm**
- **Knee-extension: 268.19 Nm**
- **RATIO: 4.8 (3.5-5.1)**

- **RSF (n=7):**
- **Elbow-flexion: 60.66 Nm**
- **Knee-extension: 253.49 Nm**
- **RATIO: 4.2 (4.2-5.3)**

- **Ratio difference: (p= 0.043)**

Scand J Med Sci Sports. 2006;16:188-196

Study 3

RIB STRESS FRACTURES IN ELITE ROWERS
-Hormonal factors and BMD:

Material:

13 male lightweight Danish national team rowers.

Aim:

To investigate possible associations
BMD in elite lightweight male row

Endurance trained male athletes display testosterone levels reduced to 60-85 % of untrained controls. (Hackney 2001, review)

Foto: Aerob og anaerob træning by Lars Michalsik and Jens Bangsbo

Foto: Kim [illegible]admand

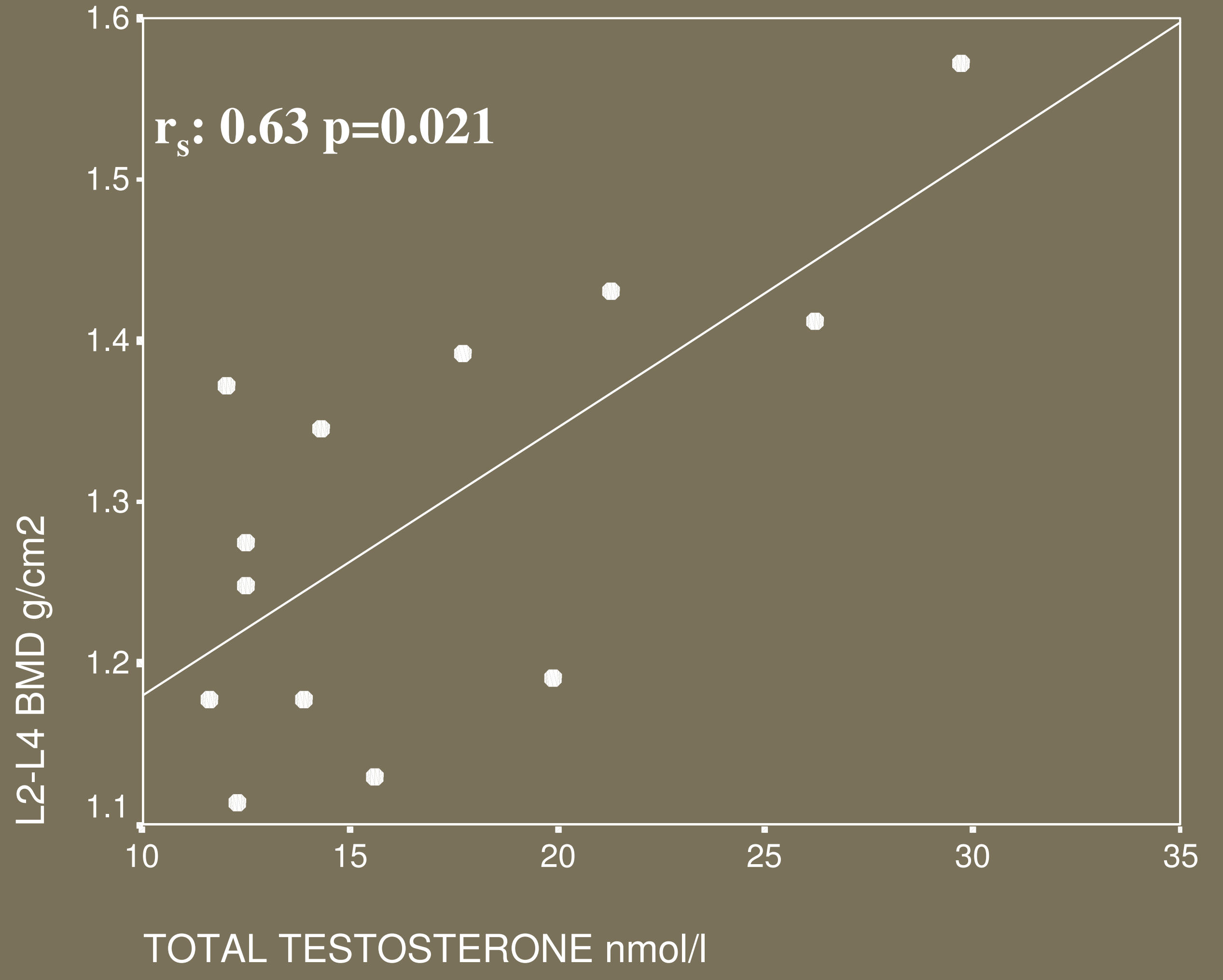
Foto : Bo Vestergaard

Study 3

Testosterone and BMD in male lightweight rowers

- Correlations:

Total Testosterone and L2-L4 BMD

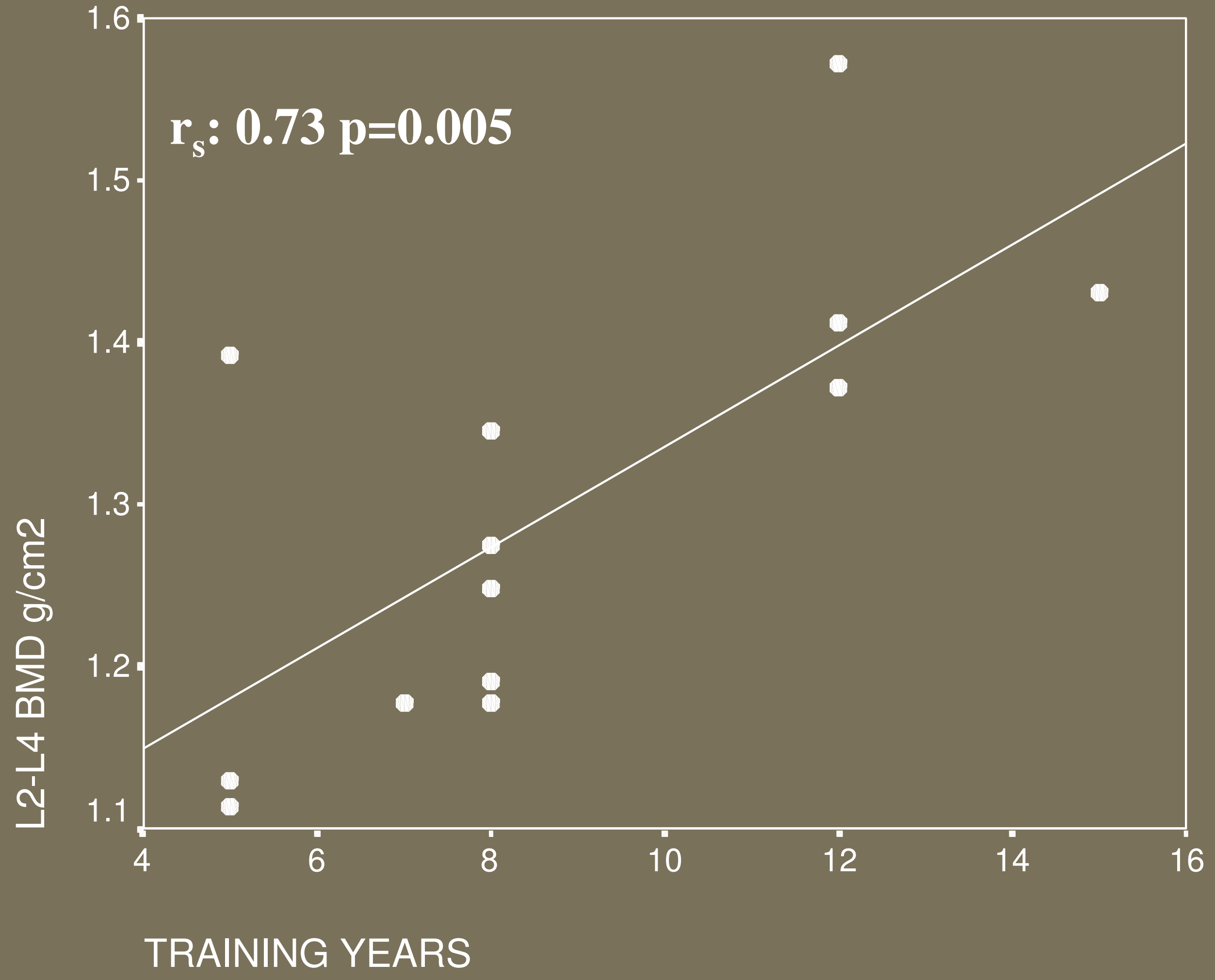


Study 3

Testosterone and BMD in male lightweight rowers

- Correlations:

L2-L4 BMD and Training Years:



Study 3

Testosterone and BMD in male lightweight rowers

- Main result:

A significant correlation between L2-L4 BMD and Testosterone remained after controlling for Training Years by calculation of partial correlation: r_s: 0.61 $p<0.05$

Int J Sport Med 2008, 29: 803-807

Study 4 & 5

Placing the rowing ergometer in slides: Implications for injury risk

Study 4 & 5

SLIDES?

Picture from: www.concept2.com

Study 4 & 5

Background:

A prospective investigation of injury incidence found that time spent on ergometer training was related to risk of injury **(Wilson F. et al. 2008)**

Study 4

Aim:

To investigate force production during ergometer rowing with and without slides.

To evaluate if placement of the ergometer in slides may reduce the risk of musculo-skeletal overuse injury.

Study 4

Hypothesis:

Rowing in slides may change the biomechanics of the rowing stroke:

1. **Increase stroke rate**
2. **Reduce Peak Force of each rowing stroke**

Study 4

Background:

Rib loading is related to handle force.
(Warden et al. 2003, Abstract)

Force production at the handle is related to the overall loading of the rower.

Compressive force up to 4.6 times body weight in female rowers - calculated from handle force.
(Morris et al. 2000, Int J Sports Med)

LBP is the most frequent injury and rib stress fracture is the injury causing the most time lost from training and competition.
(Rumball et al. 2005 Sports Med)

Study 4

Material:

22 National Team Rowers:

8 women (5 lightweight and 3 open class)

14 men (9 lightweight and 5 open class)

Picture from: World Championships 2006

Picture from: World Championships 2007, Simon Lorenz

Study 4

Methods:

Handle force was measured with a strain-gauge

Handle excursion was measured with a potentiometer attached to the fly-wheel axis

Sampling frequency: 1000 Hz

Picture from: www.concept2.com

Study 4 & 5

Test procedure:

- **Self paced warm-up.**
- **2 x 3.5 minutes of ergometer rowing at 75-80 % of maximal power output**
  - with and without slides in a randomized order.
- **1 trial of similar duration in stationary ergometer with stroke rate identical to slide trial.** (Study 4)

Study 4 & 5

Results:

Equal external power output and exercise intensity:

Men and Women (N=22):

	Power:
Slides:	281.9 Watt (76.8 % max)
Stationary:	280.1 Watt (76.3 % max)

	Heart Rate:
Slides:	158.4 bpm (86.1 % max)
Stationary:	156.6 bpm (85.1 % max)

Study 4 & 5

Results:

Stroke Rate:

Men (N=14):

Slides:	28.7	
Stationary:	25.9	
Difference:	2.8	(95 % CI: 2.0-3.6)

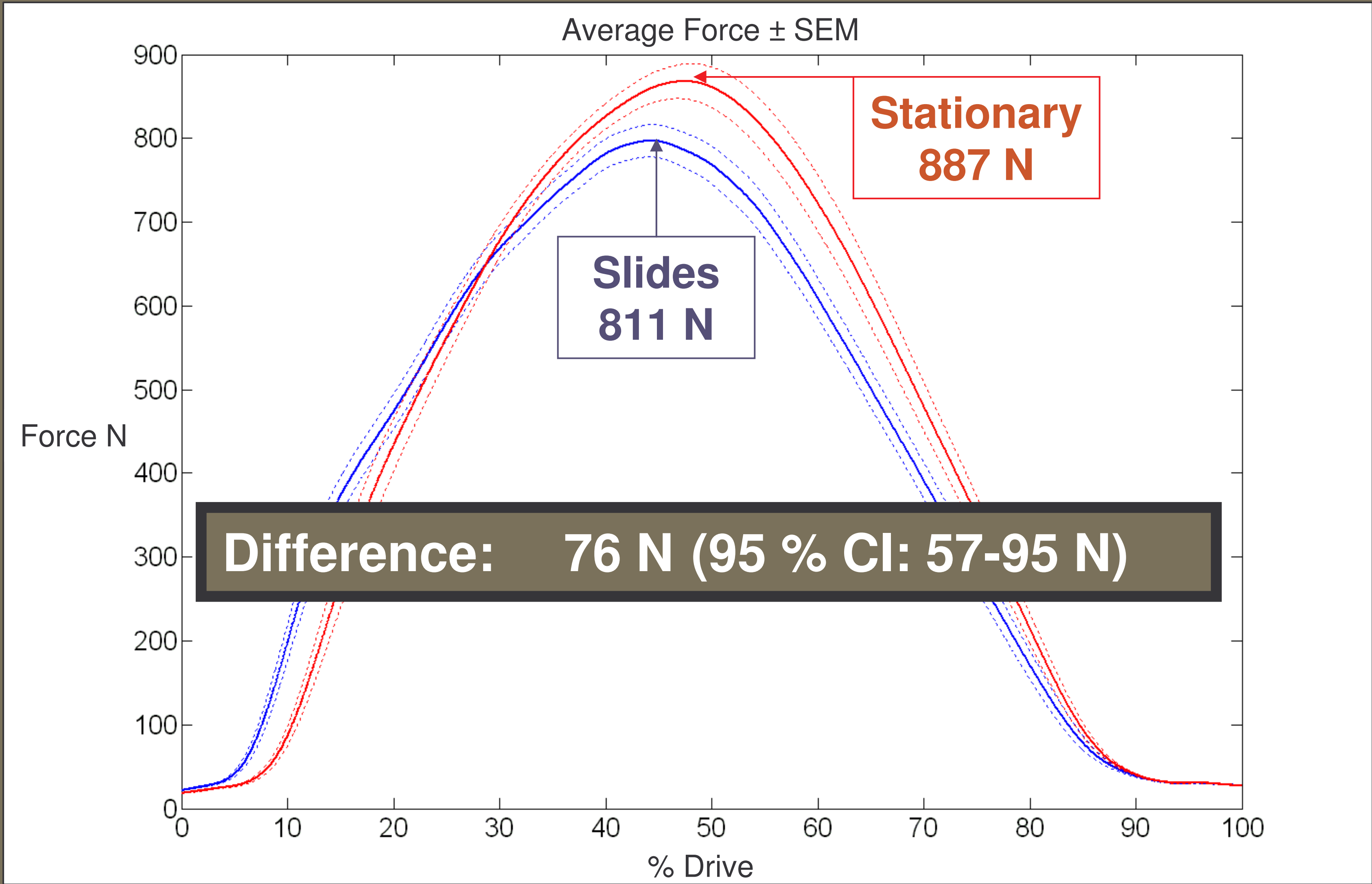
Women (N=8):

Slides:	25.7	
Stationary:	25.0	
Difference:	0.7	(95 % CI: 0.08-1.6)

Study 4

Results:

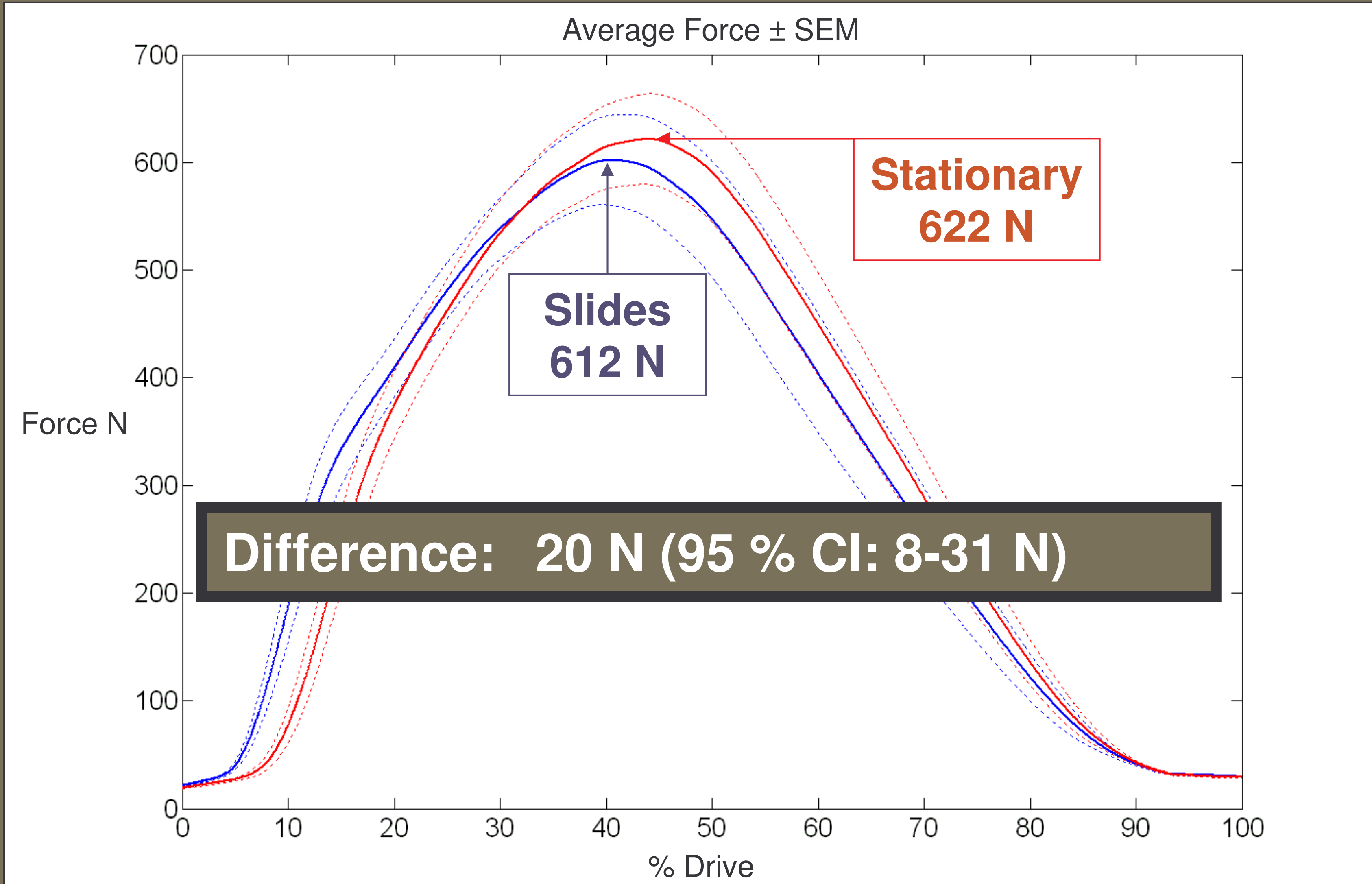
Peak Force Men (N=14):



Study 4

Results:

Peak Force Women (N=8):



Difference: 20 N (95 % CI: 8-31 N)

Study 4

Conclusion:

Placement of the rowing ergometer in slides decreased the Peak Force production in each rowing stroke.

The external power output was maintained.

Picture from: World Championships 2007, Simon Lorenz

Study 4

Perspectives:

Rowing in slides may reduce the risk of overuse injury without compromising the training efficiency and rowing performance of the rowers.

Prospective controlled studies are required to test this hypothesis.

Picture from: www.concept2.com

Study 5

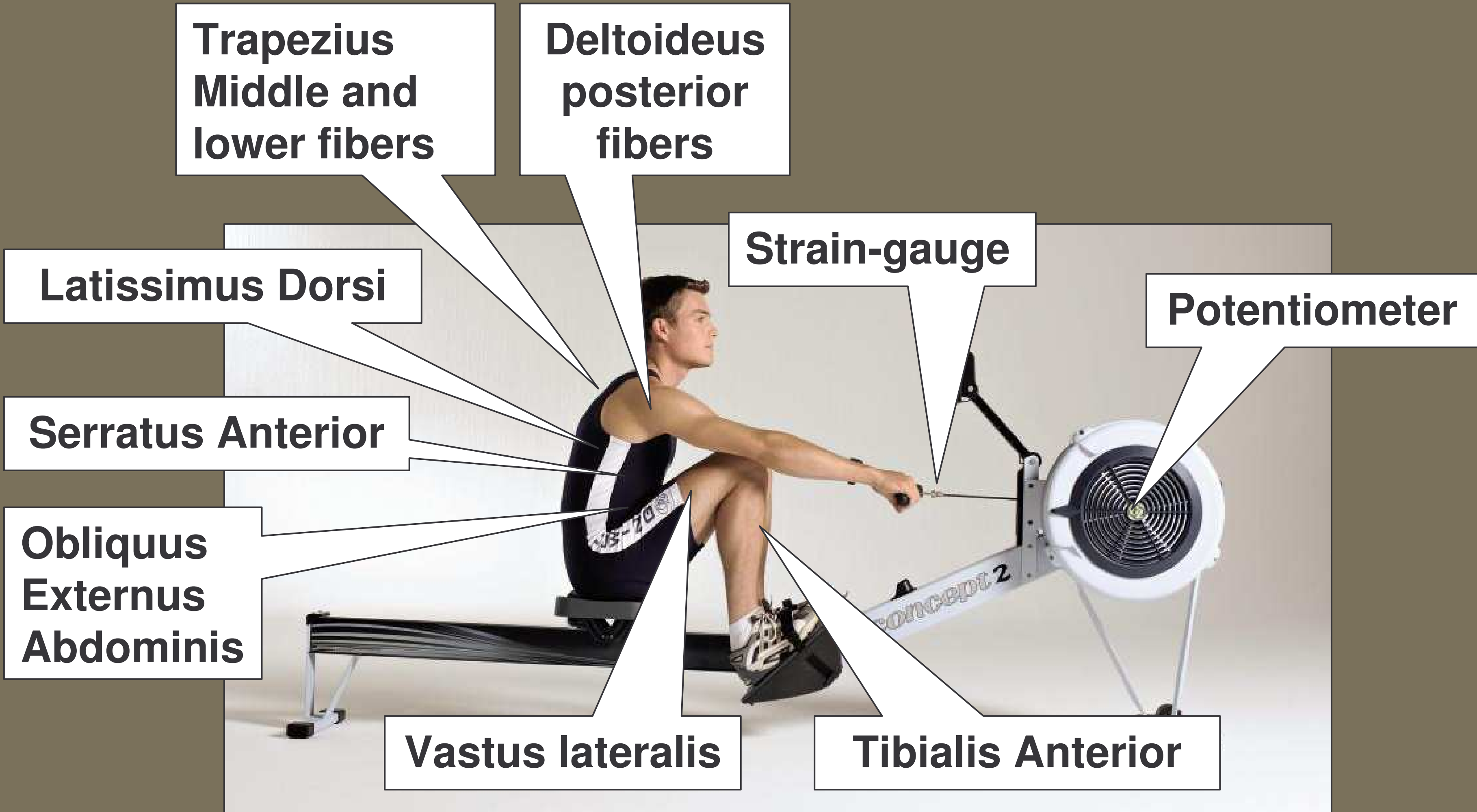
Aim:

To investigate neuromuscular activity of muscles suggested to be involved in the development of rib stress fractures during ergometer rowing with and without slides.

To relate neuromuscular activity to force production during ergometer rowing.

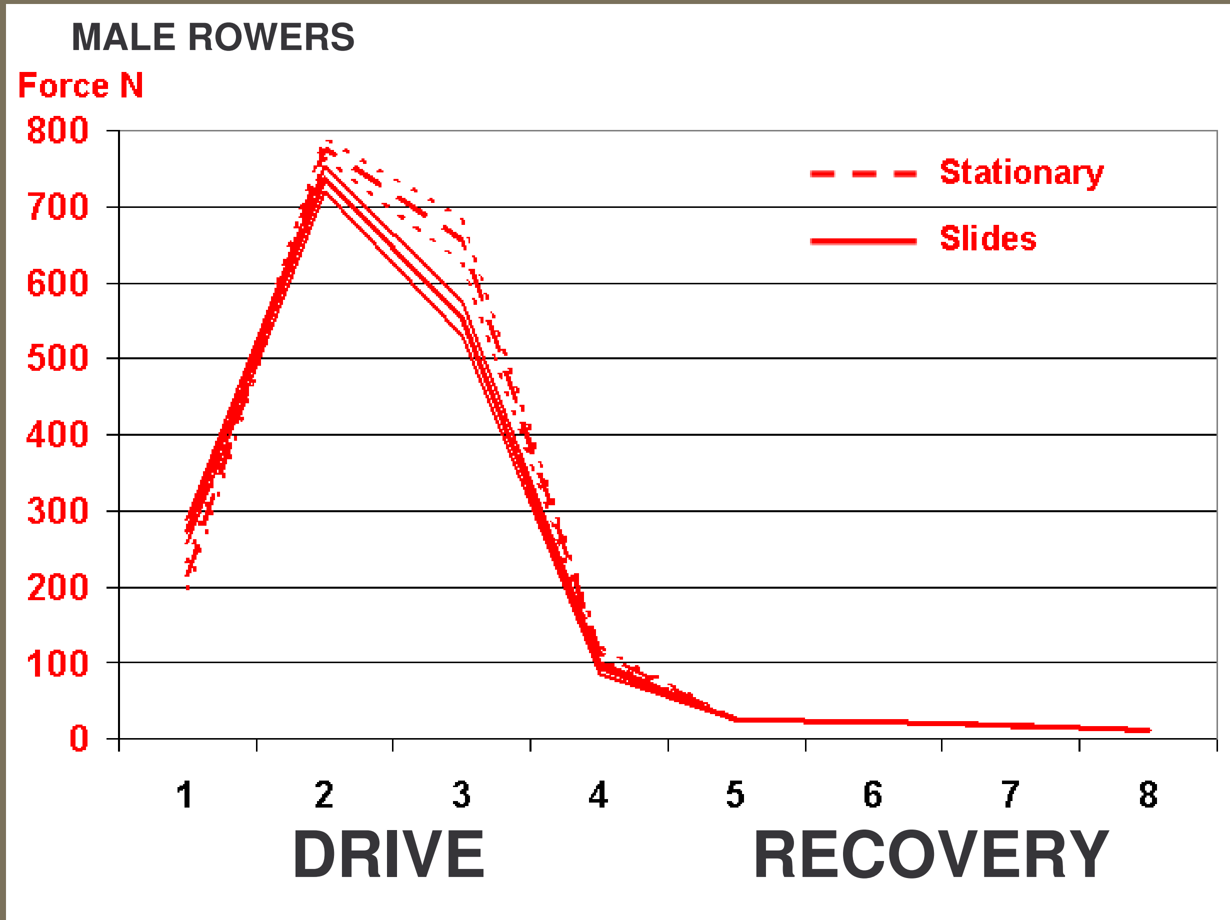
Methods:

Study 4 + EMG signals from the following muscles:

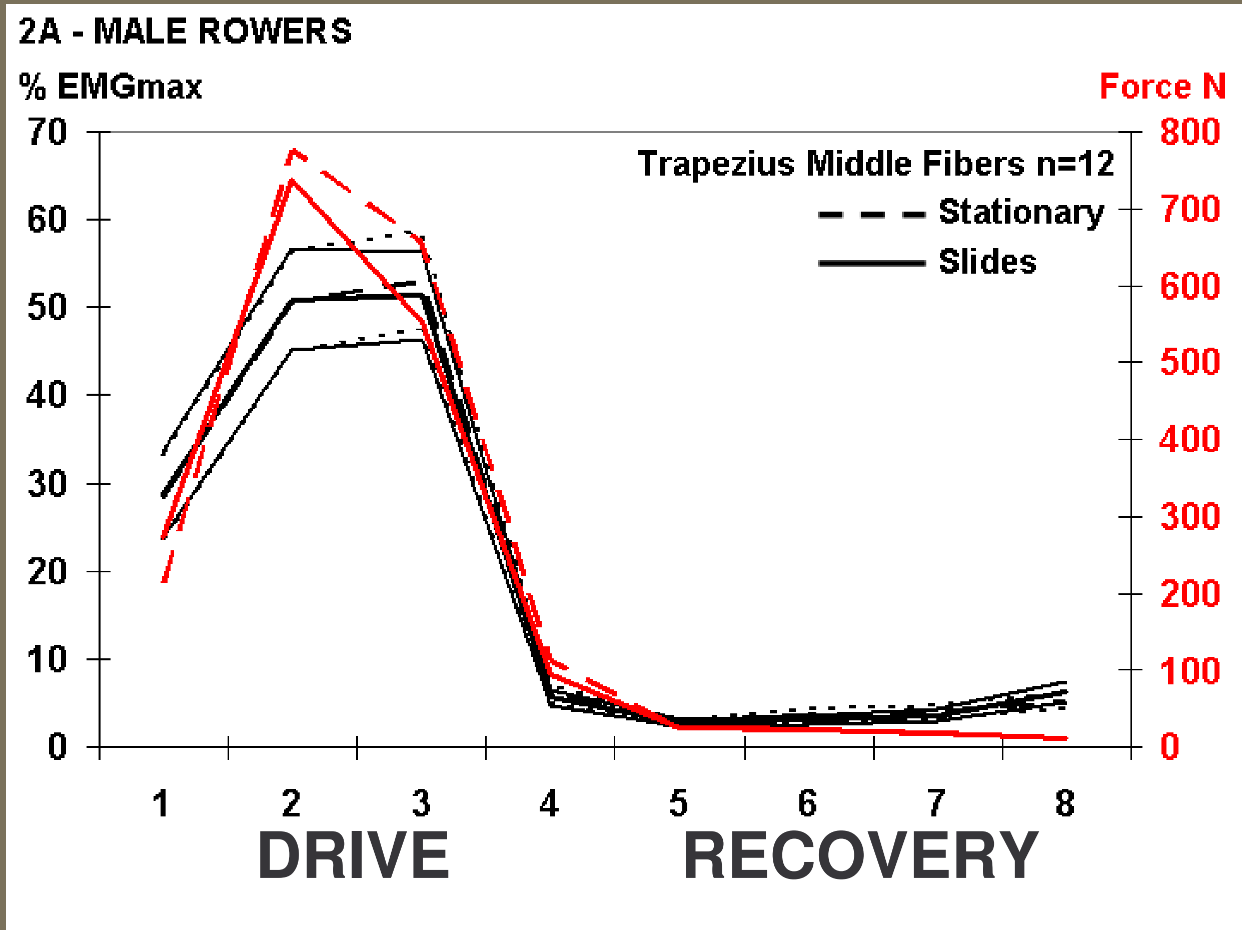


Picture from: www.concept2.com

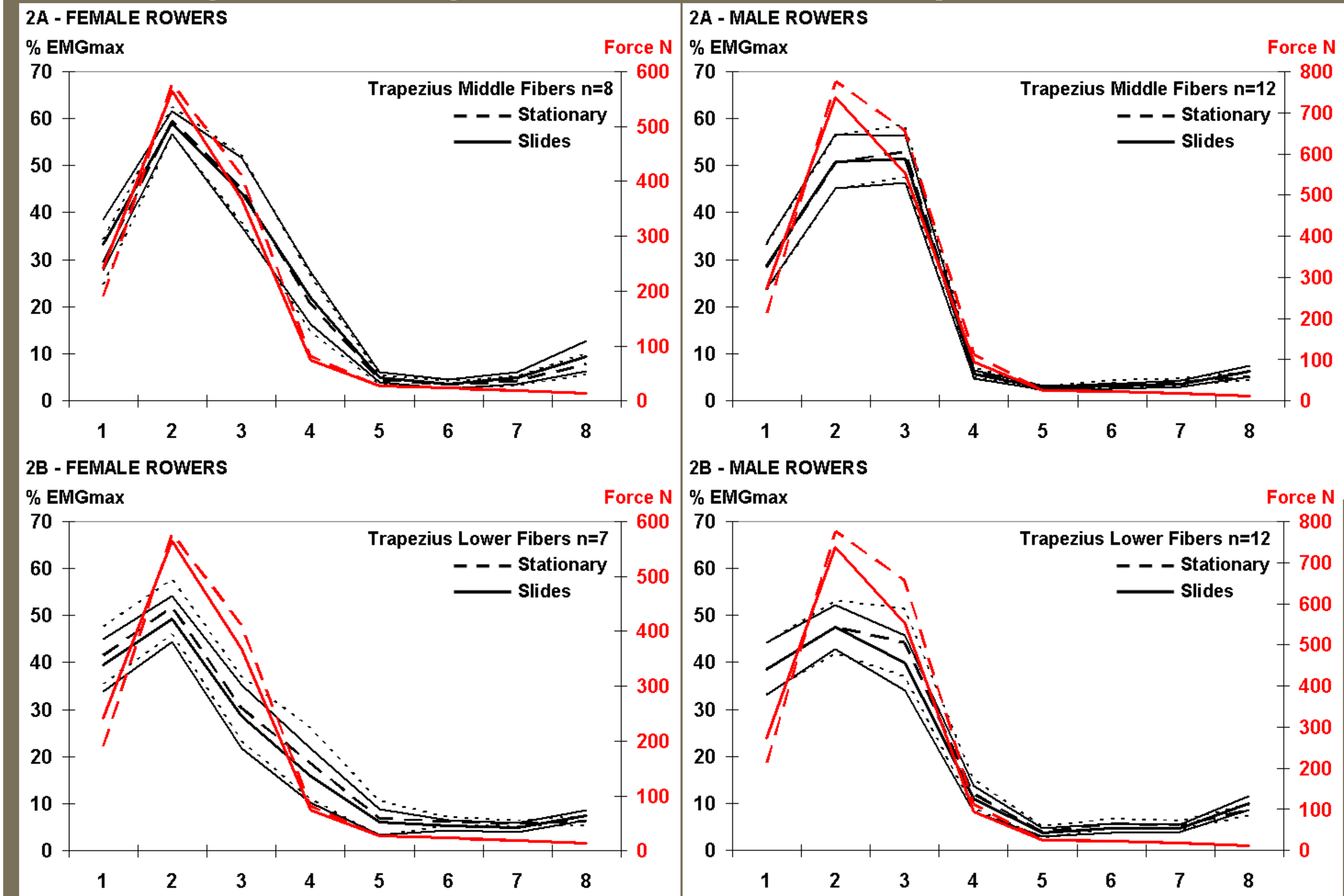
Handle Force:



EMG:


2A - MALE ROWERS
% EMGmax
Force N
Trapezius Middle Fibers n=12
Stationary
Slides
70
60
50
40
30
20
10
0
800
700
600
500
400
300
200
100
0
1
2
3
4
5
6
7
8
DRIVE
RECOVERY

Average normalized EMG from thoracic muscles during the rowing stroke divided into 8 phases:



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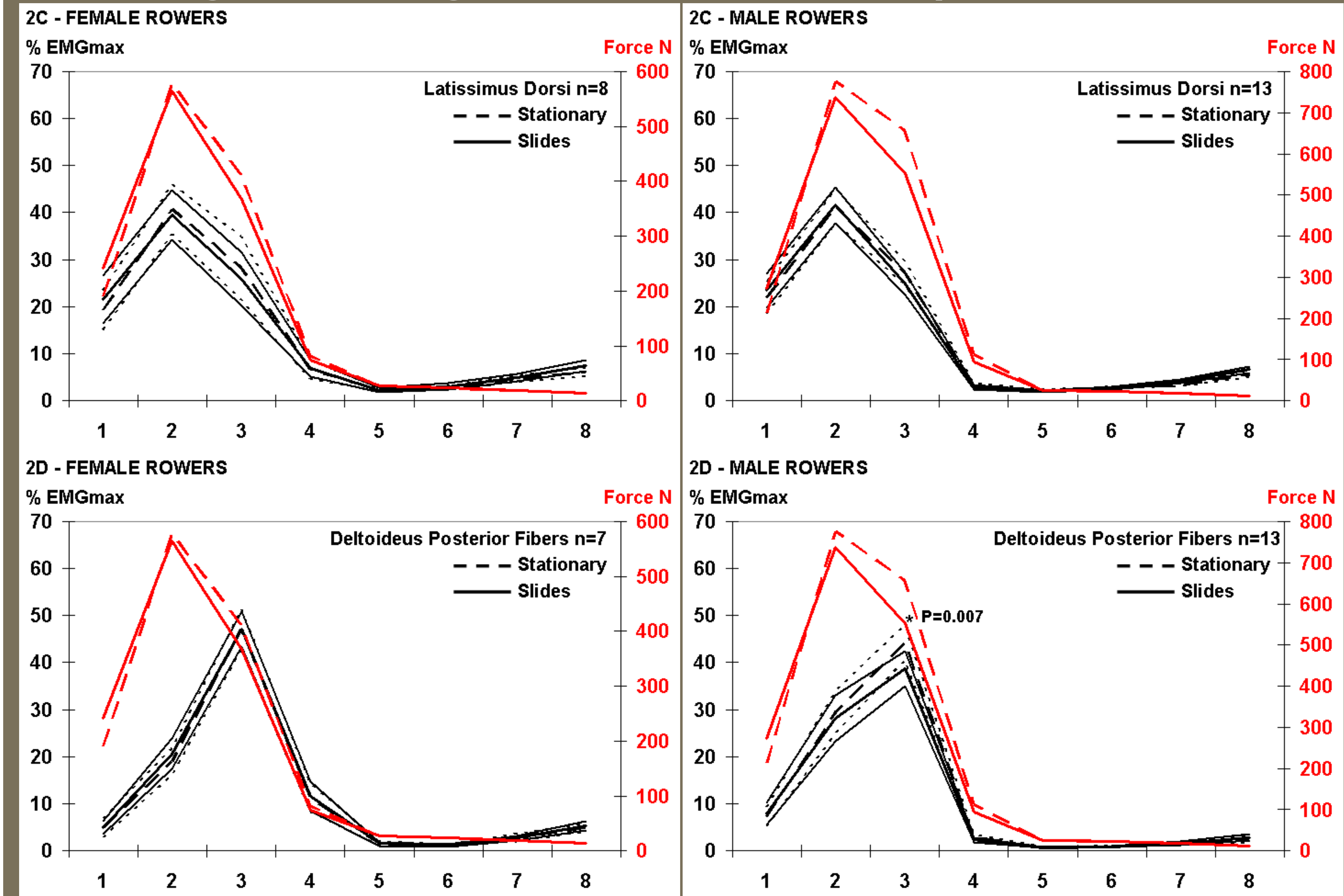

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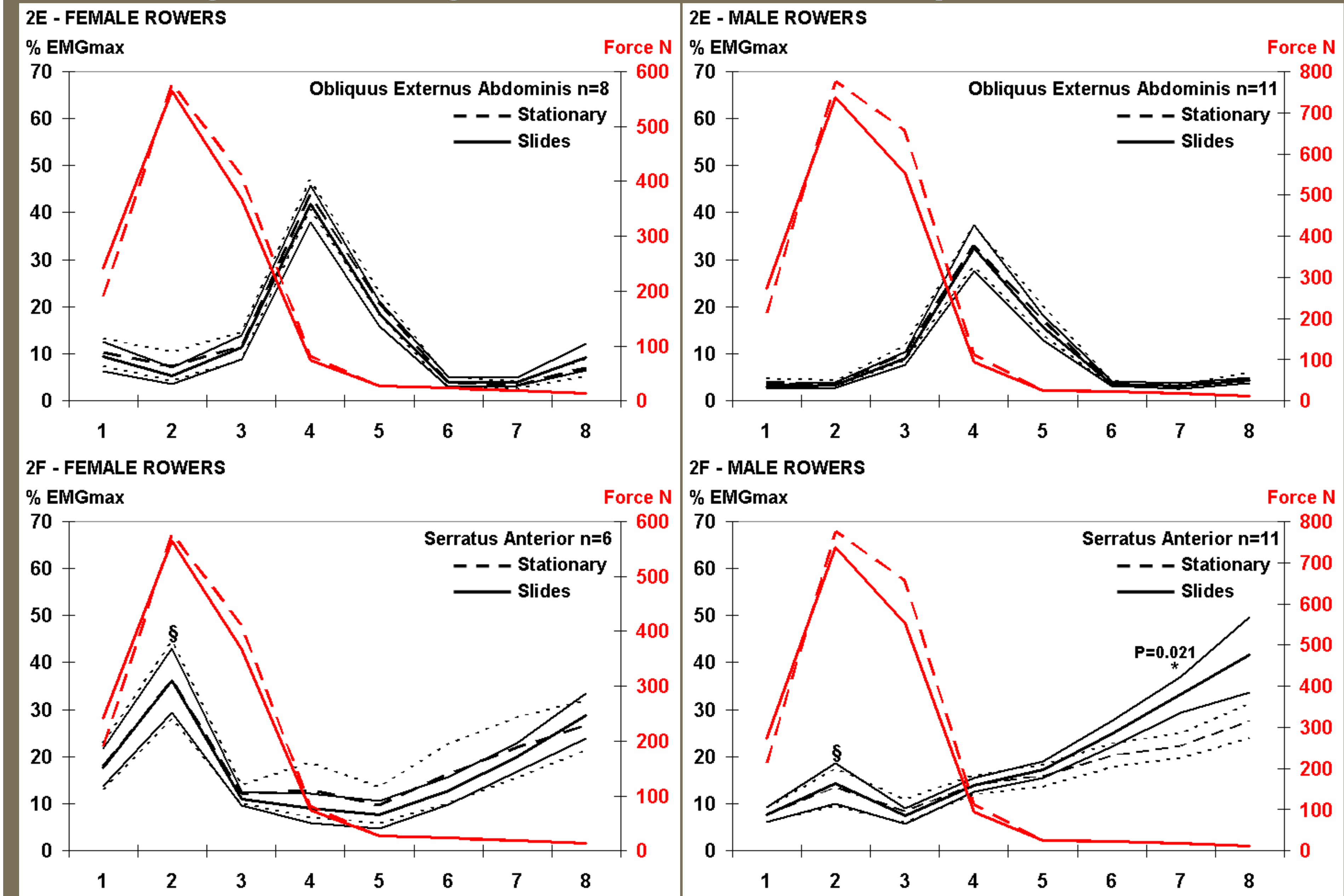
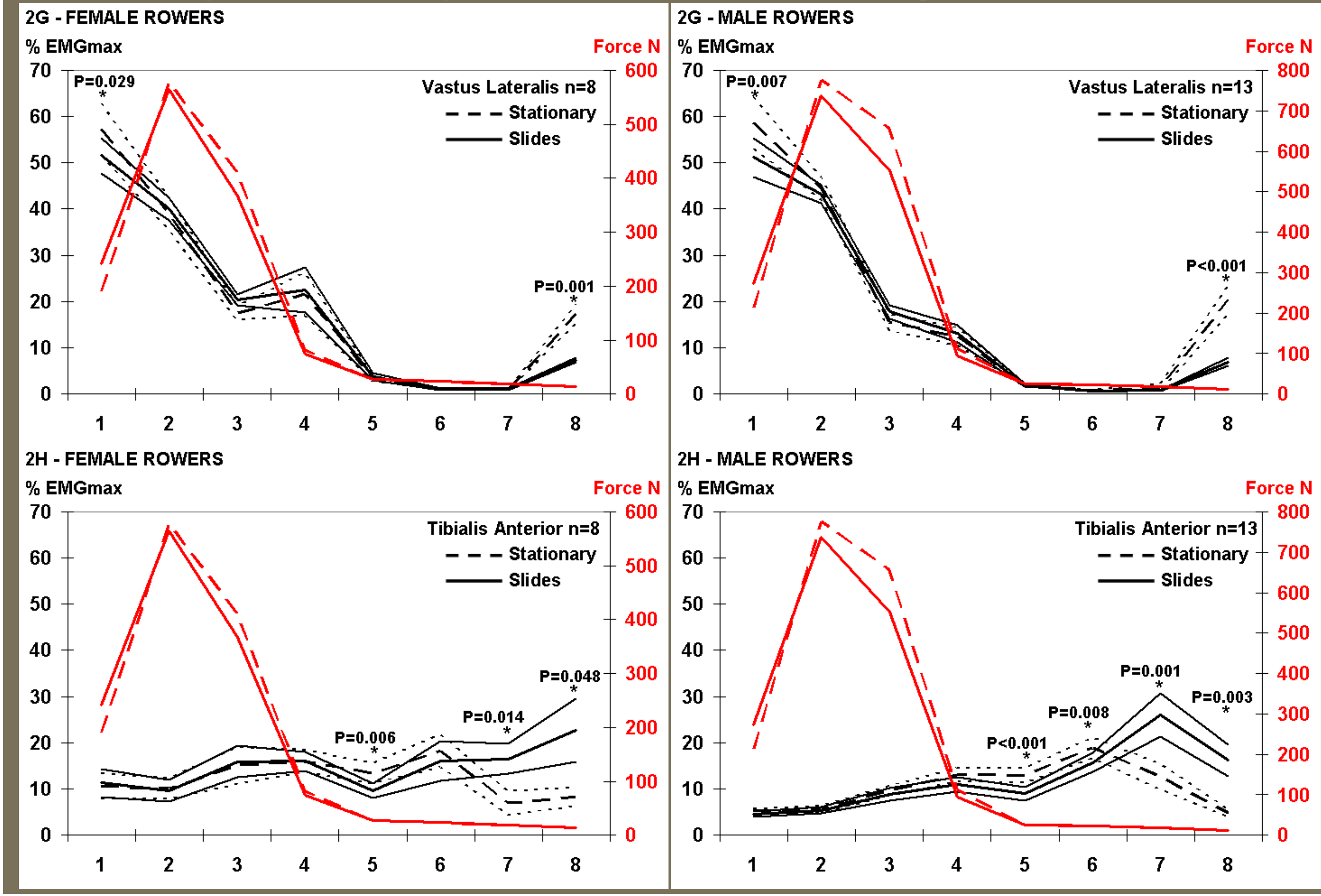


Average normalized EMG from leg muscles during the rowing stroke divided into 8 phases:

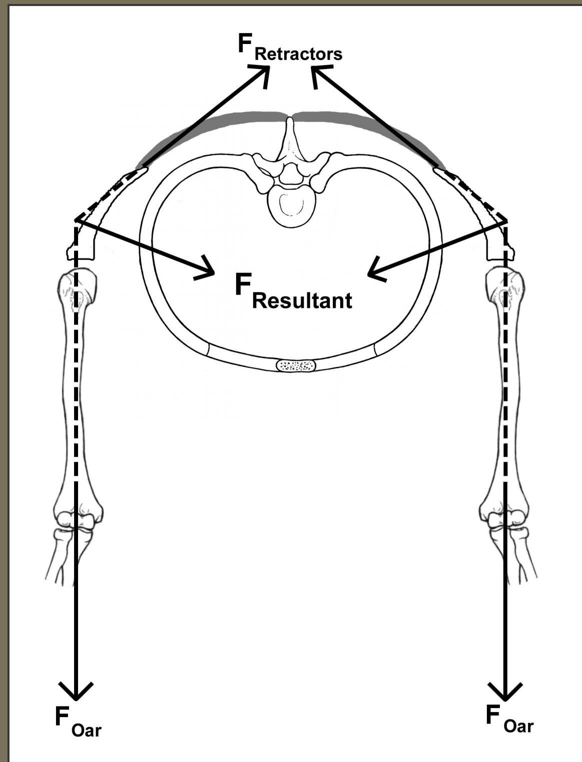


Timing of Peak EMG of thoracic muscles and Peak Force:

Peak Force

Peak EMG Trapezius: 106-185 ms

Peak EMG Latissimus Dorsi: 57-129 ms



Warden et al. 2002

Conclusions:

Placement of the rowing ergometer on slides affected the neuromuscular activity of the leg muscles more than the thoracic muscles.

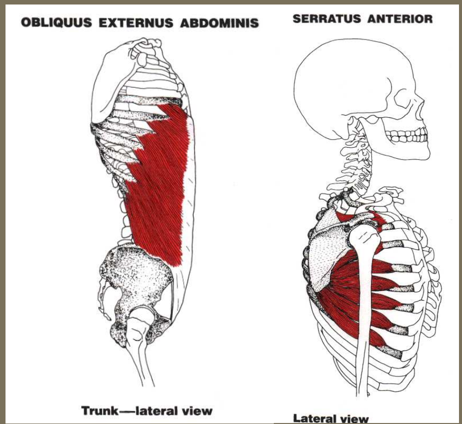
Regardles of ergometer condition the timing of Peak neuromuscular activity of the scapular retractors coincided with the timing of Peak Force at the handle.

A gender difference in neuromuscular activity of m. serratus anterior was observed.

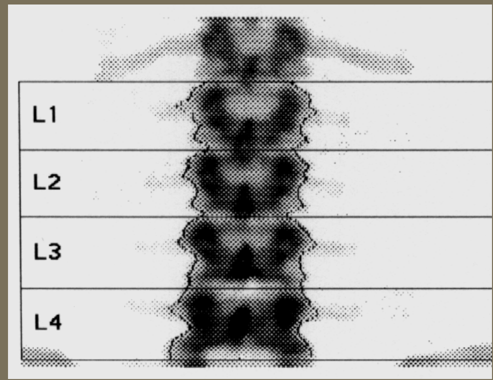
Picture from: World Championships 2006, Peter Spurrier

Thank you!

Summary:



NO



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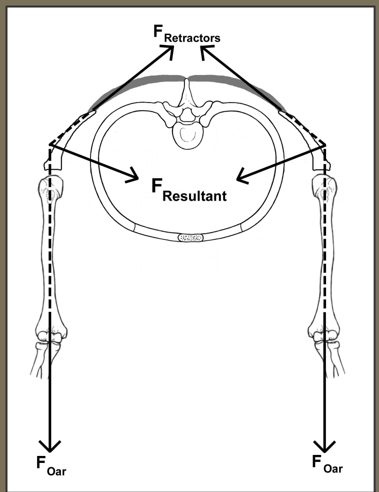

YES

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