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Muscle, Nerves, Bone –  
Falls and Fractures

2018 Bone Curriculum Symposium

2 March 2018

La Hulpe, Brussels

The answer is in the interconnectiveness.  
The whole is more than the sum of its parts.

The integrity and overall function of an organism is based on the interplay of its subsystems and its exchange with the environment.

## Who is our client?

How do we delineate our system?

Is speaking about „holistic“ approach  
only an esoteric blabbing? Poetry?

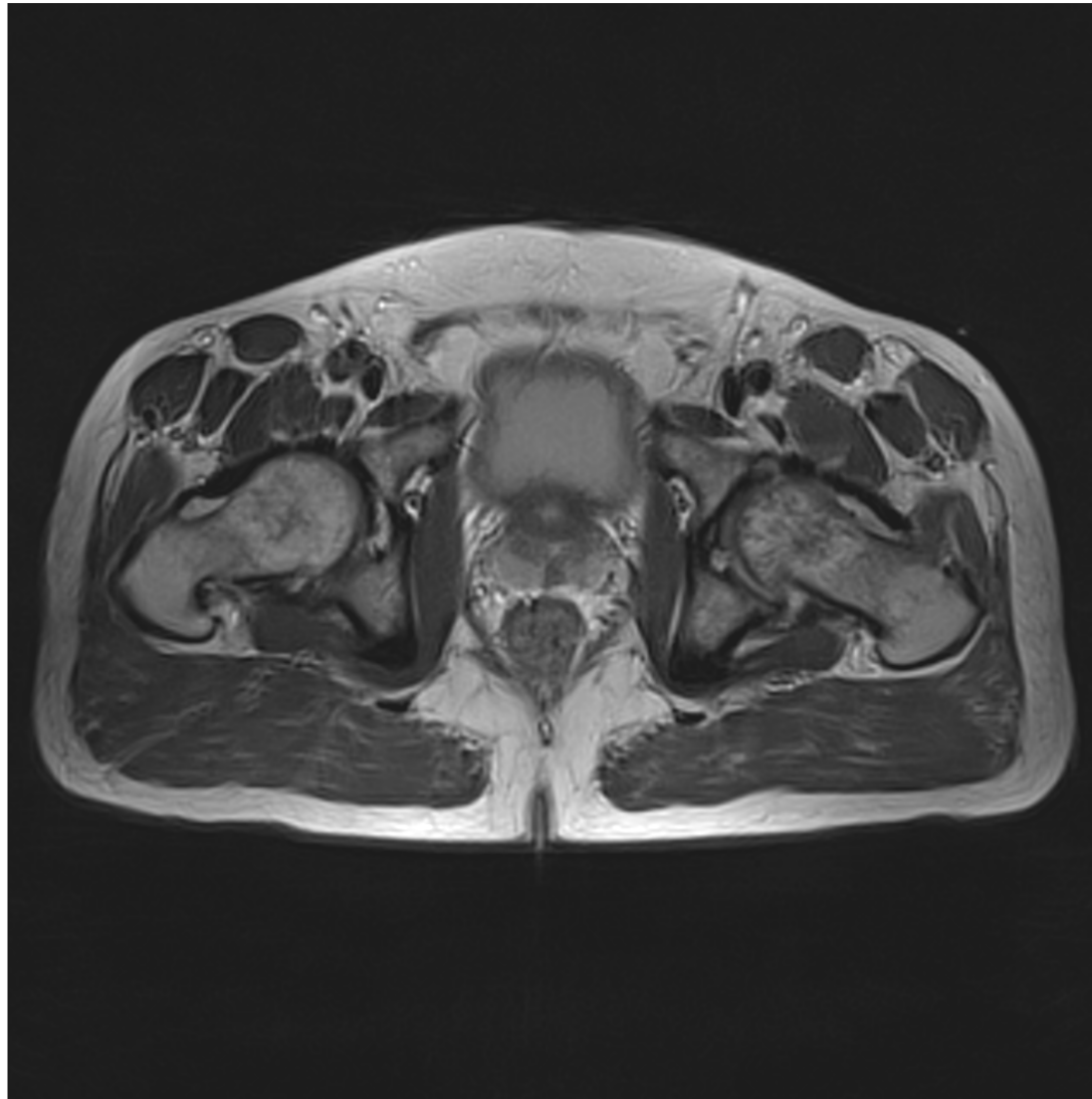
Wasting of time?



A clock can be understood by a mechanistic reduction of thinking and repair.

The clockmaker is not an appropriate model for a physician - if we understand the difference between *complicated* and *complex*, or difference between *accumulation* and the product of interrelated factors.

# Coxarthrosis and muscular sequelae



Julis Wolff, Berlin 1870, Wolff's law

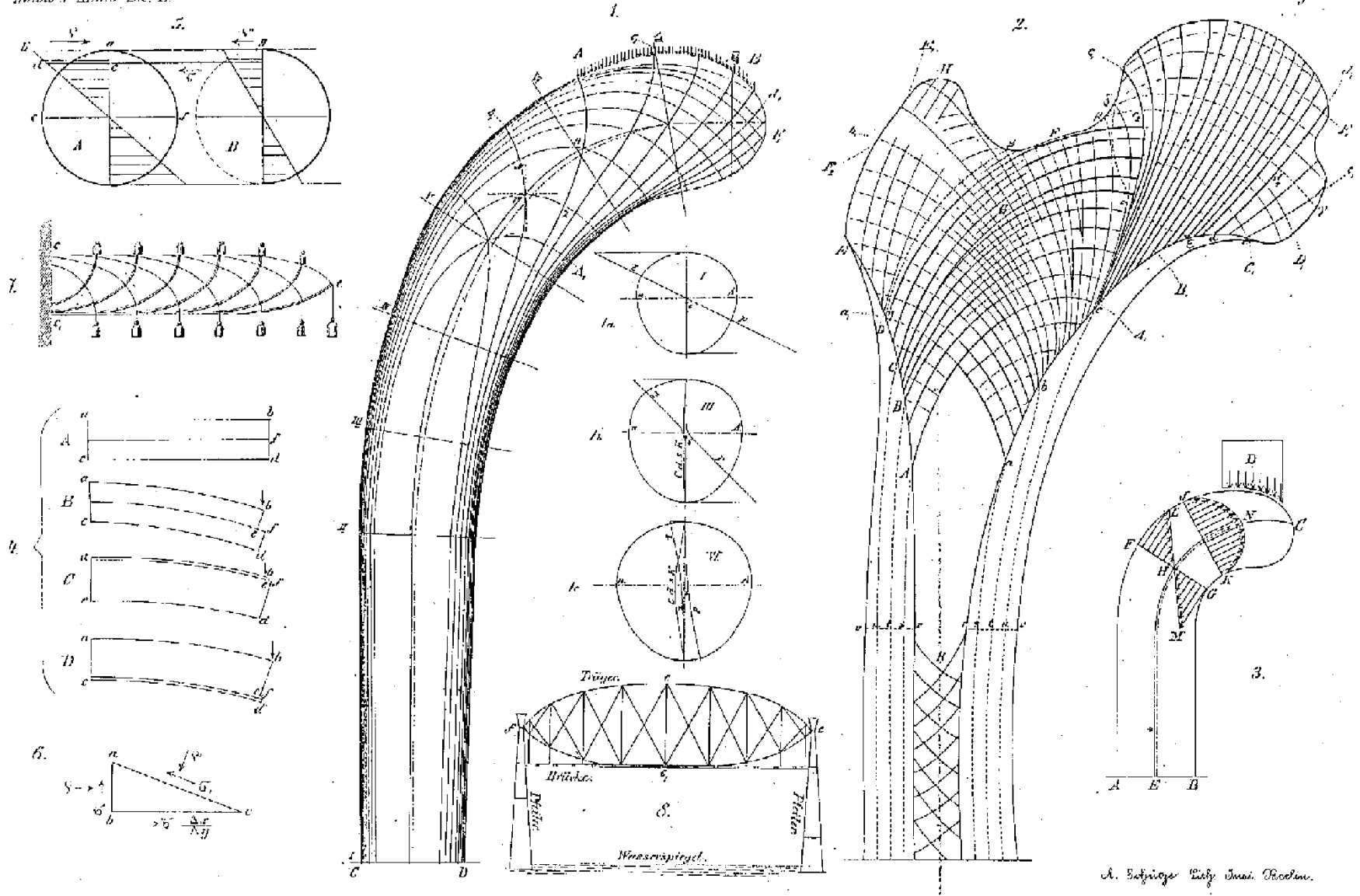
H. Frost & W. Jee, Utah-Paradigm



*J Wolff: Über die innere Architektur der Knochen und ihre Bedeutung für die Frage vom Knochenwachstum*

*Wolfenbüttel, 1786, Bd. I.*

*Taf. XII.*



*A. Schriege Lith. Insi. Boden.*

# Static force on the Tibia on single forefoot stand

Ground reaction force: 1 · body weight

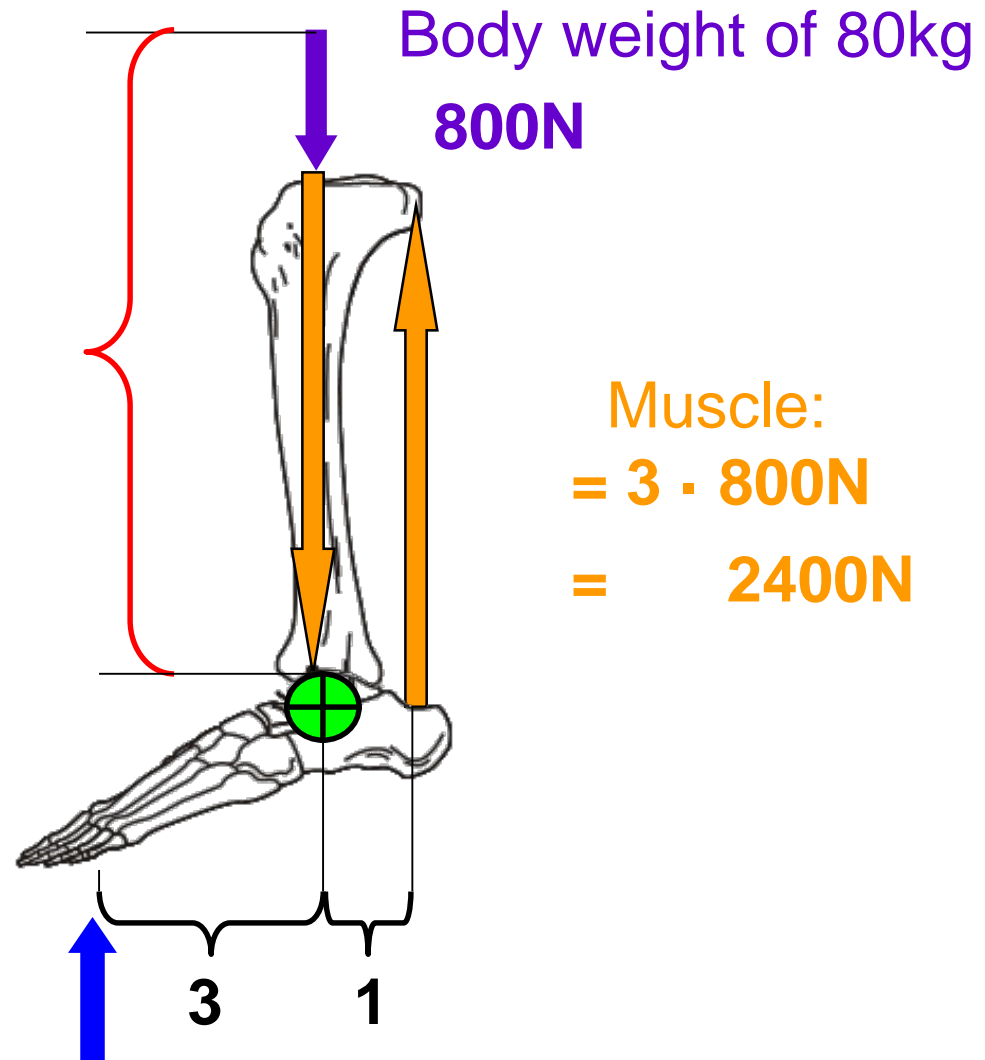
Force on tibia:

**2400N**

**+ 800N**

**= 3200N**

**4 times body weight**



$$F_{\text{Ground}} = 1 \cdot 800\text{N} = 800\text{N (measurement)}$$

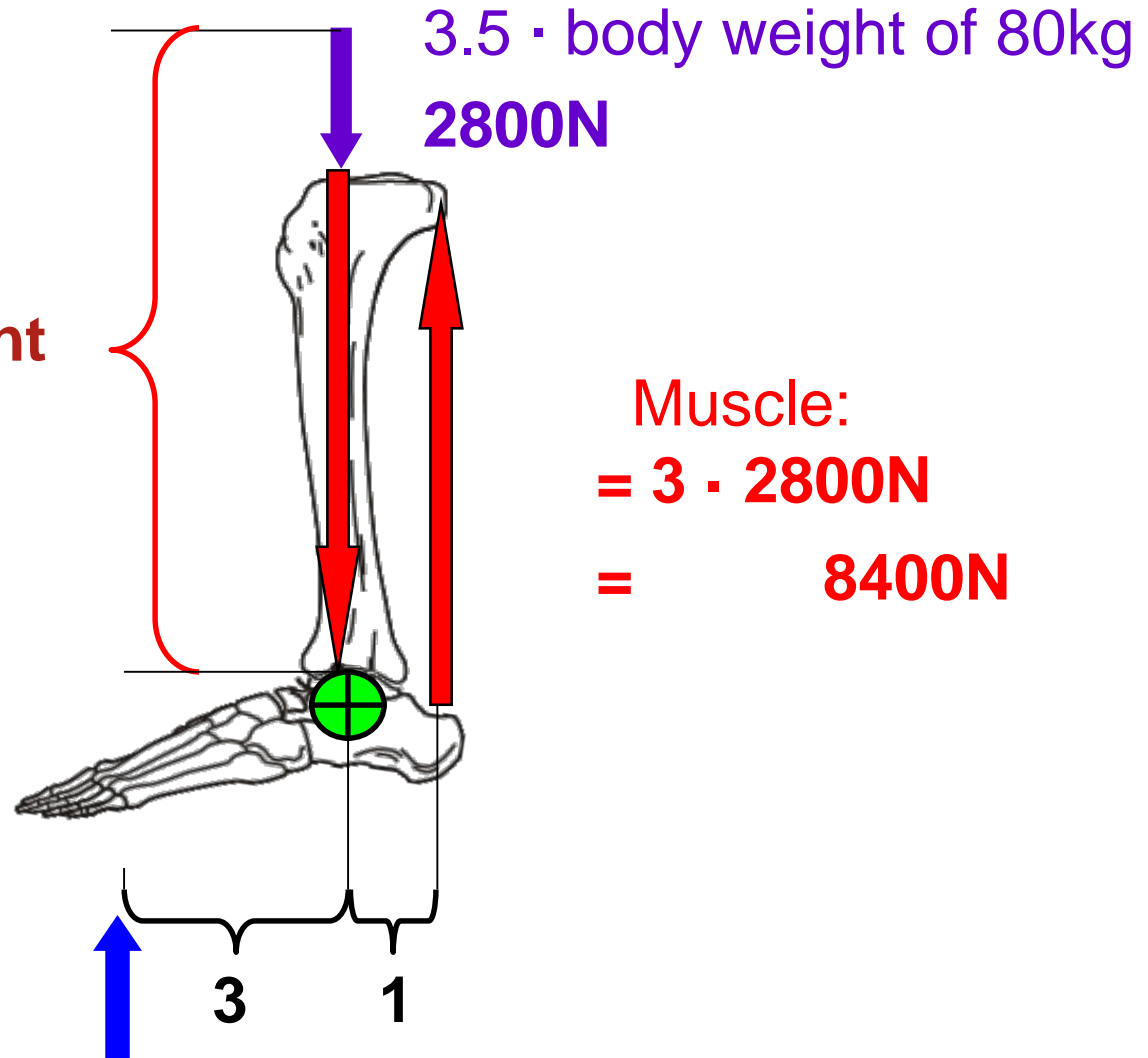
# Force on the Tibia during one leg jump on the forefoot

Typical peak ground reaction force after puberty: 3.5·body weight

**Force on Tibia:**

$$\begin{aligned} & \mathbf{8400N} \\ + & \mathbf{2800N} \\ = & \mathbf{11200N} \end{aligned}$$

**14 times body weight**




$$F_{\text{Ground}} = 3.5 \cdot 800N = 2800N \text{ (measurement)}$$





**Force**



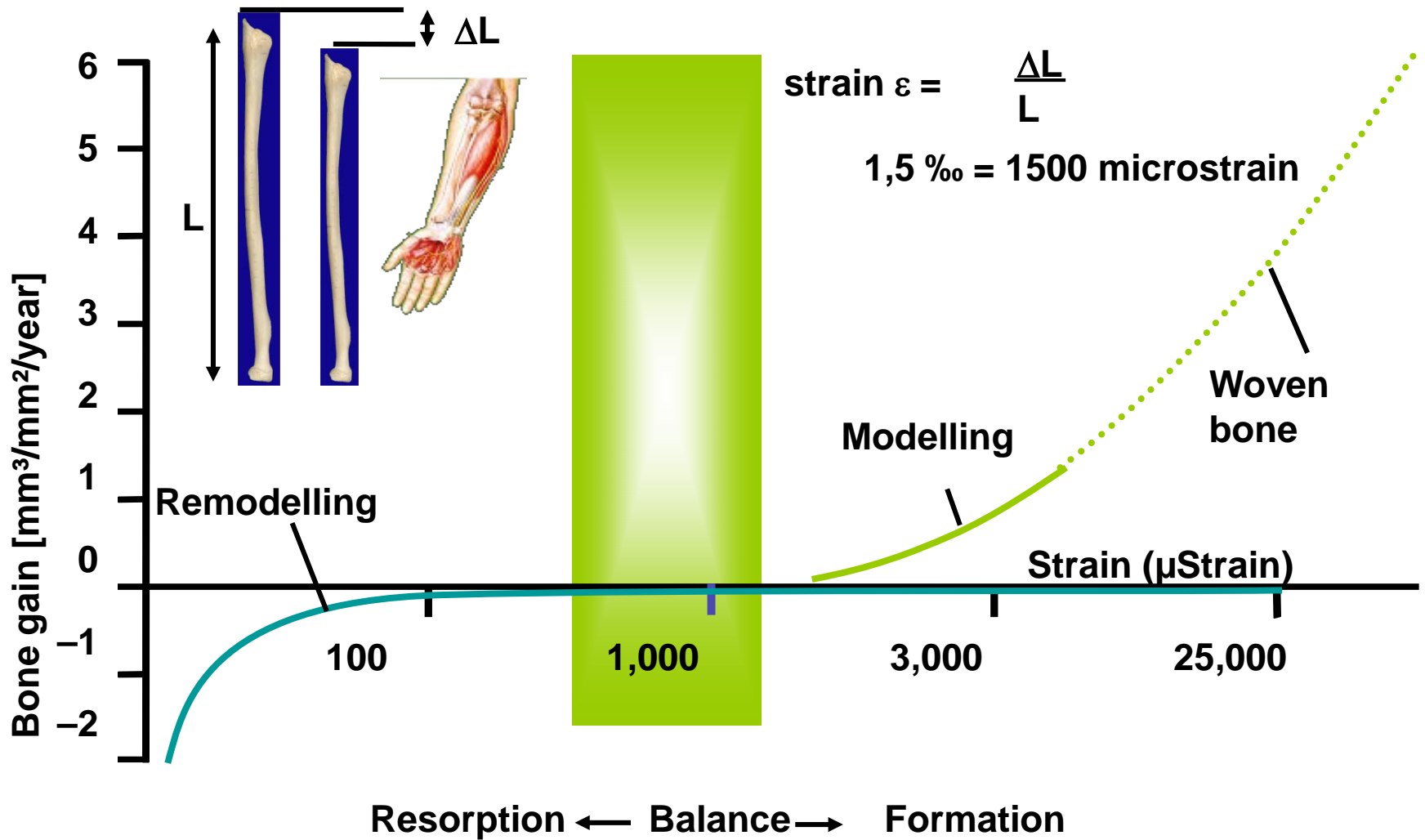
**Deformation**

**Force**

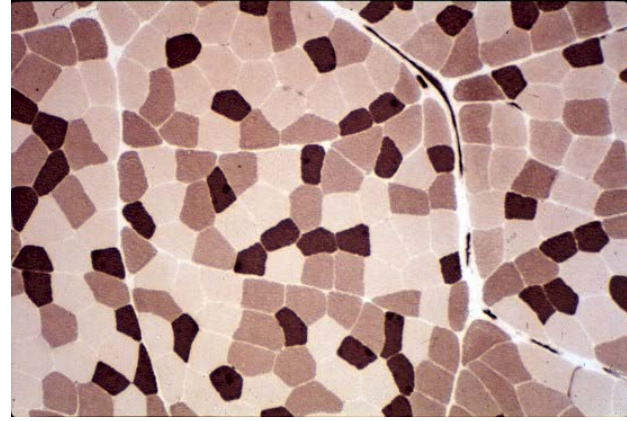
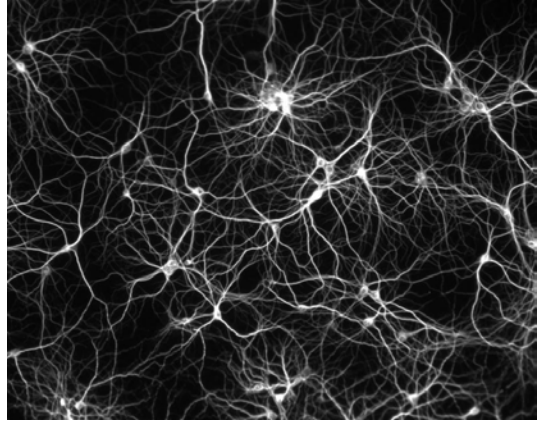
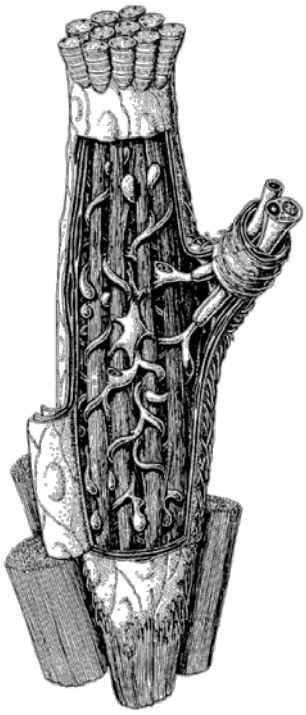


**Force causes strain**

# Regulation of bone strength



# Neuro-muscular-skeletal system





Floria J

APL

SHOPPING FEST



Coca-Cola



Why does a muscle disease cause a short leg?



**Shrinking of bone by poliomyelitis.**

**No force loading during growth.**

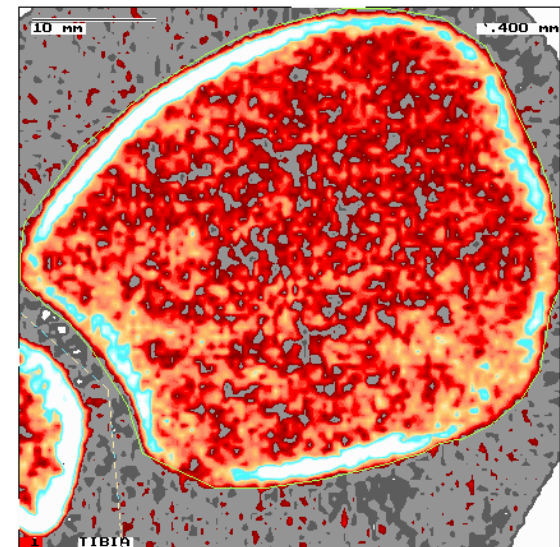
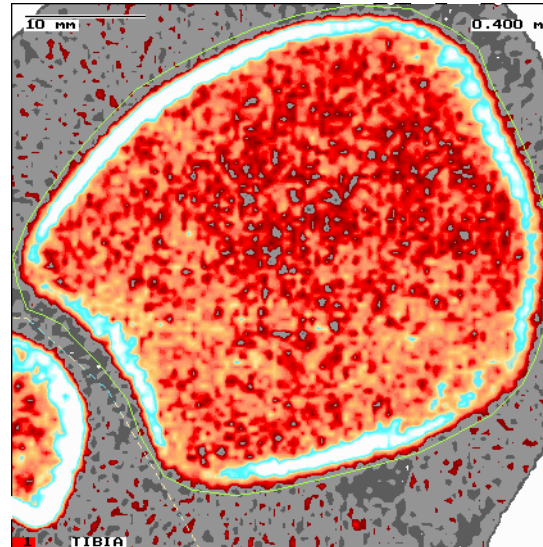
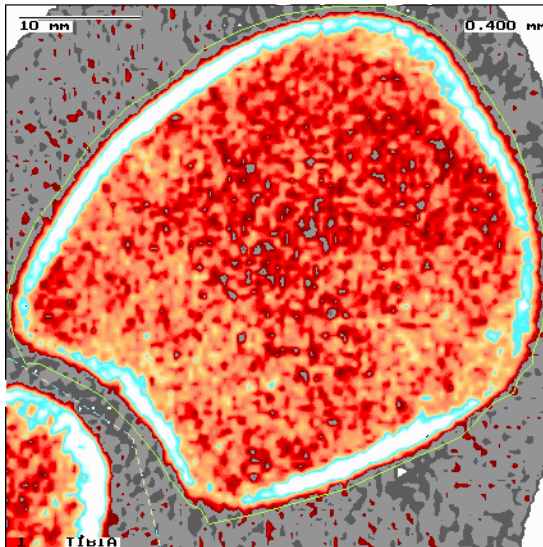


Muscle loss during bed rest study

- We all know the deleterious influence of inactivity and immobility, the complications of prolonged sitting and prolonged bed rest.
- Bed rest studies are an appropriate research setting to investigate the impact of immobility.

# Felsenberg et al. (Toulouse Bed Rest)

Immobilization for 3 months



Trabecular density at the distal tibia [ $\text{mg}/\text{cm}^3$ ]

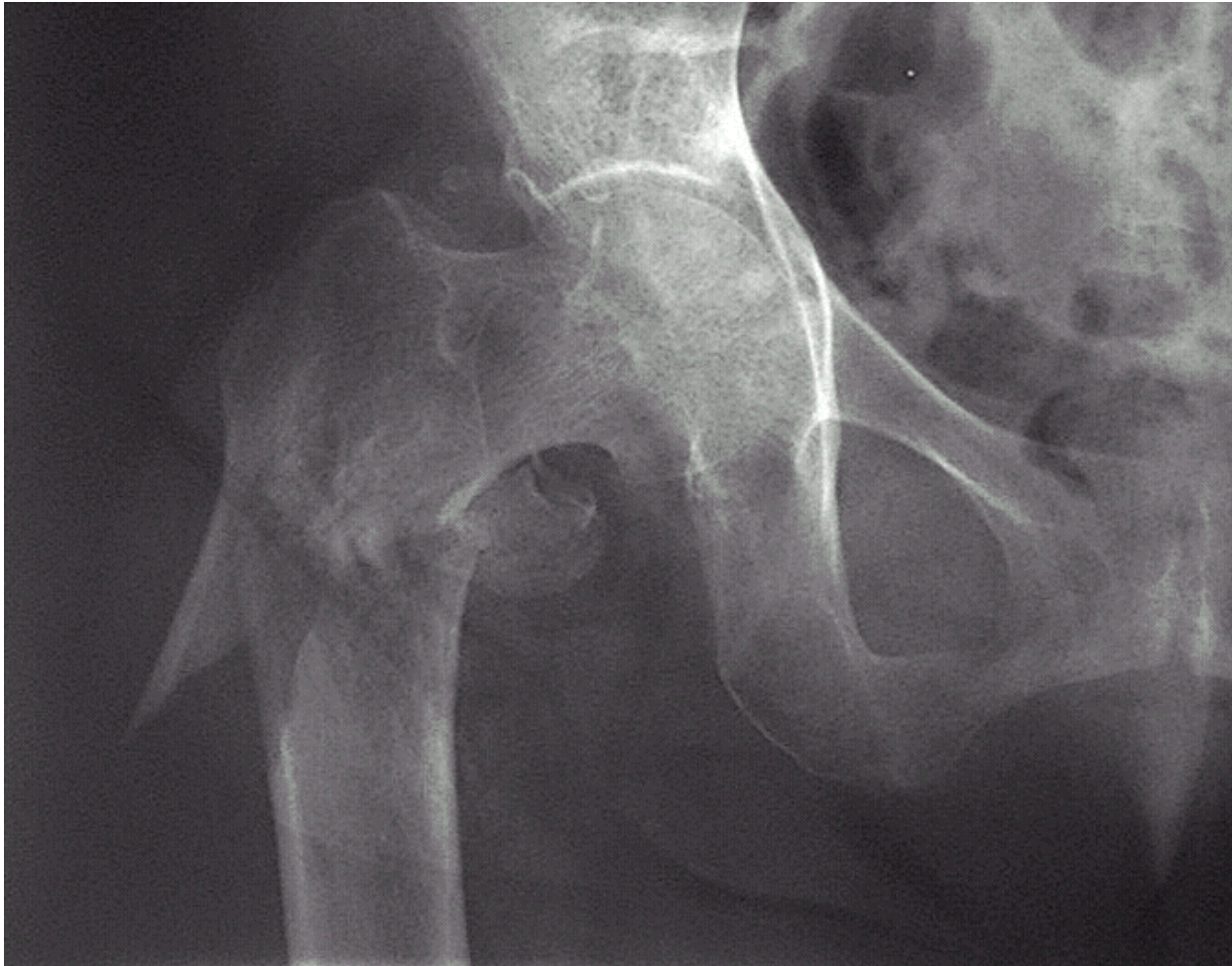
279,2

269,8

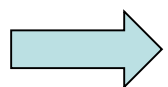
225,3

Accompanying bone loss during bed rest study





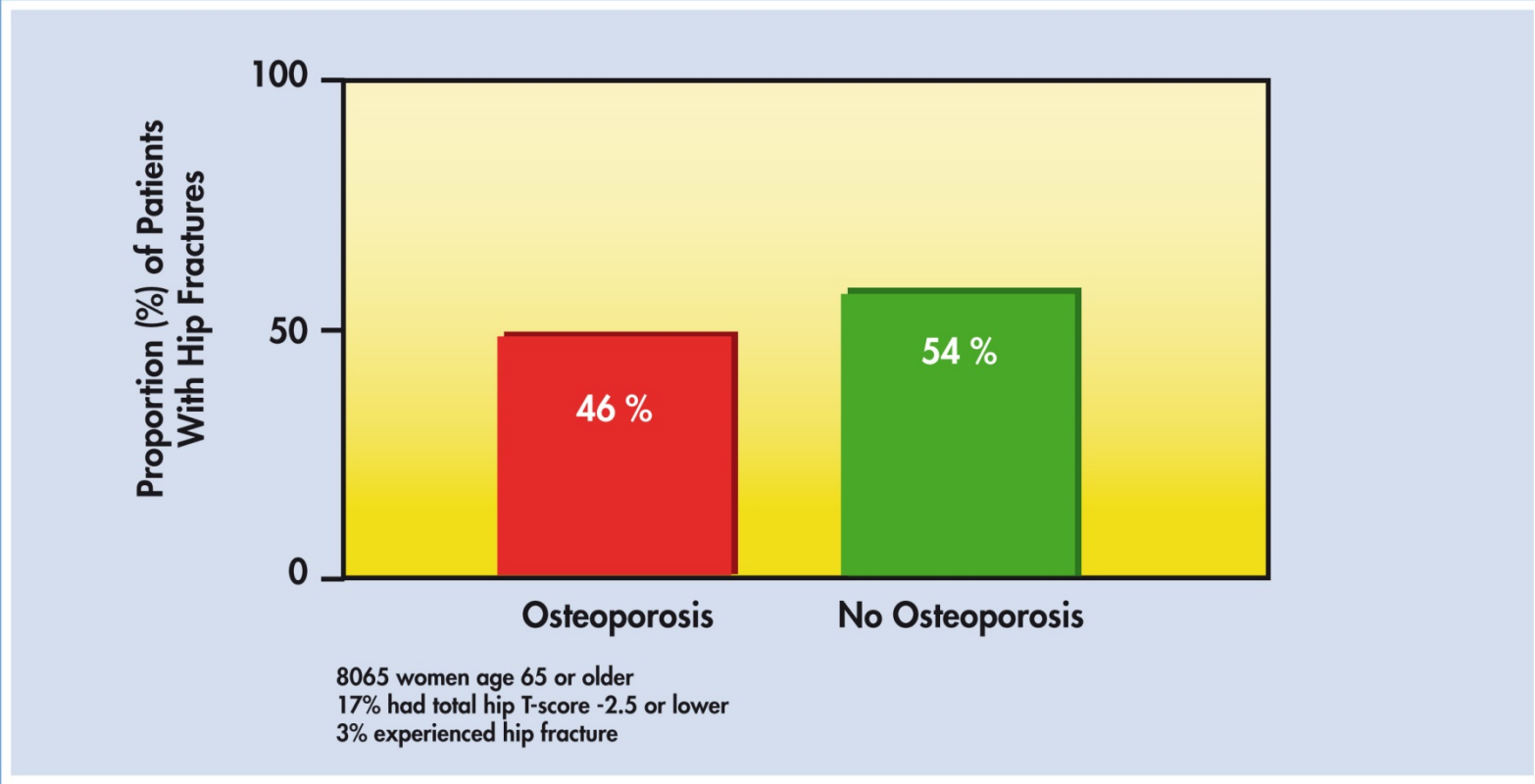
ca. 20 % additional mortality



ca. 20 % additional nursing home admission

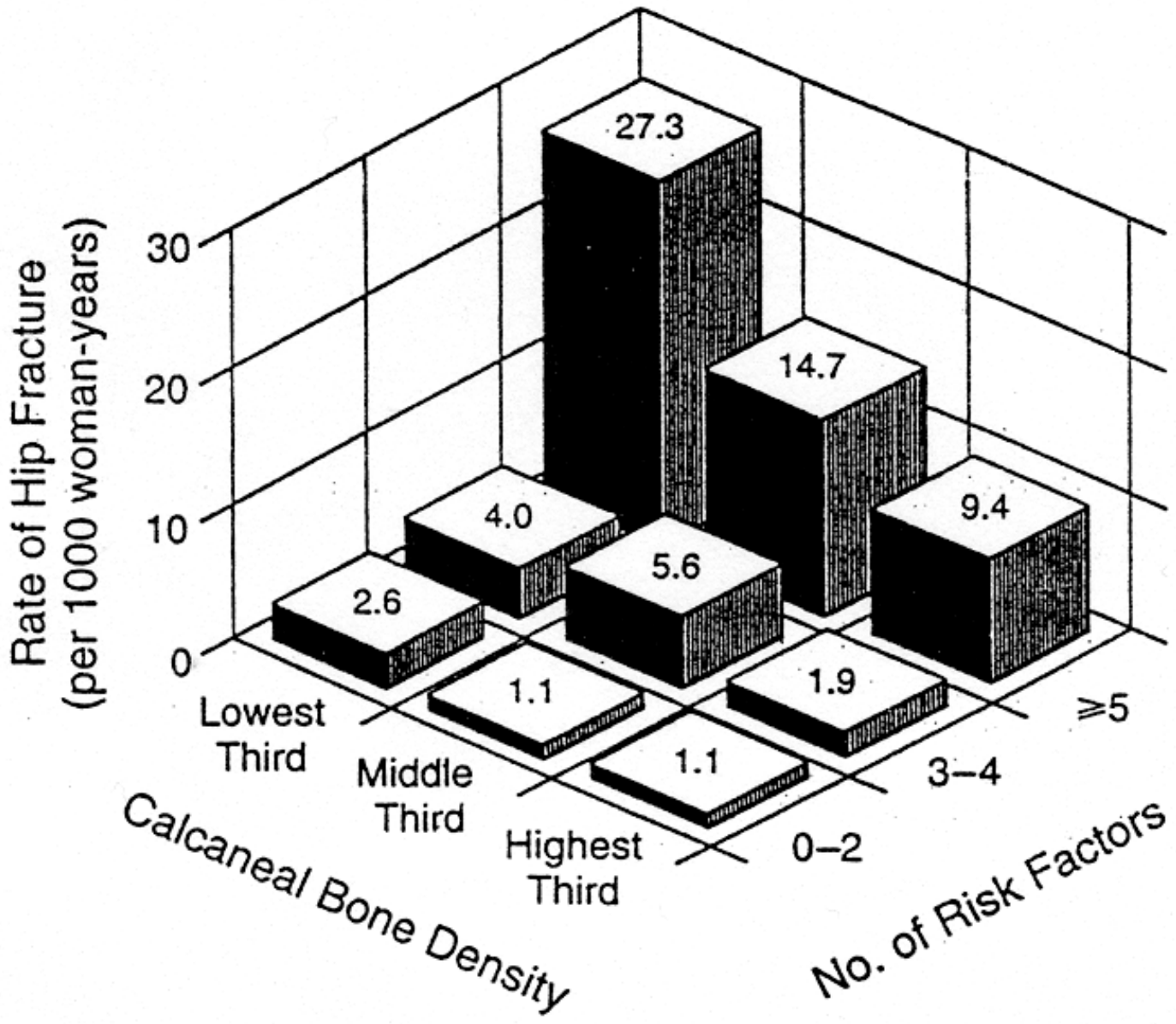
# Less than 50% of hip fracture patients have osteoporosis

## Study of Osteoporotic Fractures (SOF)



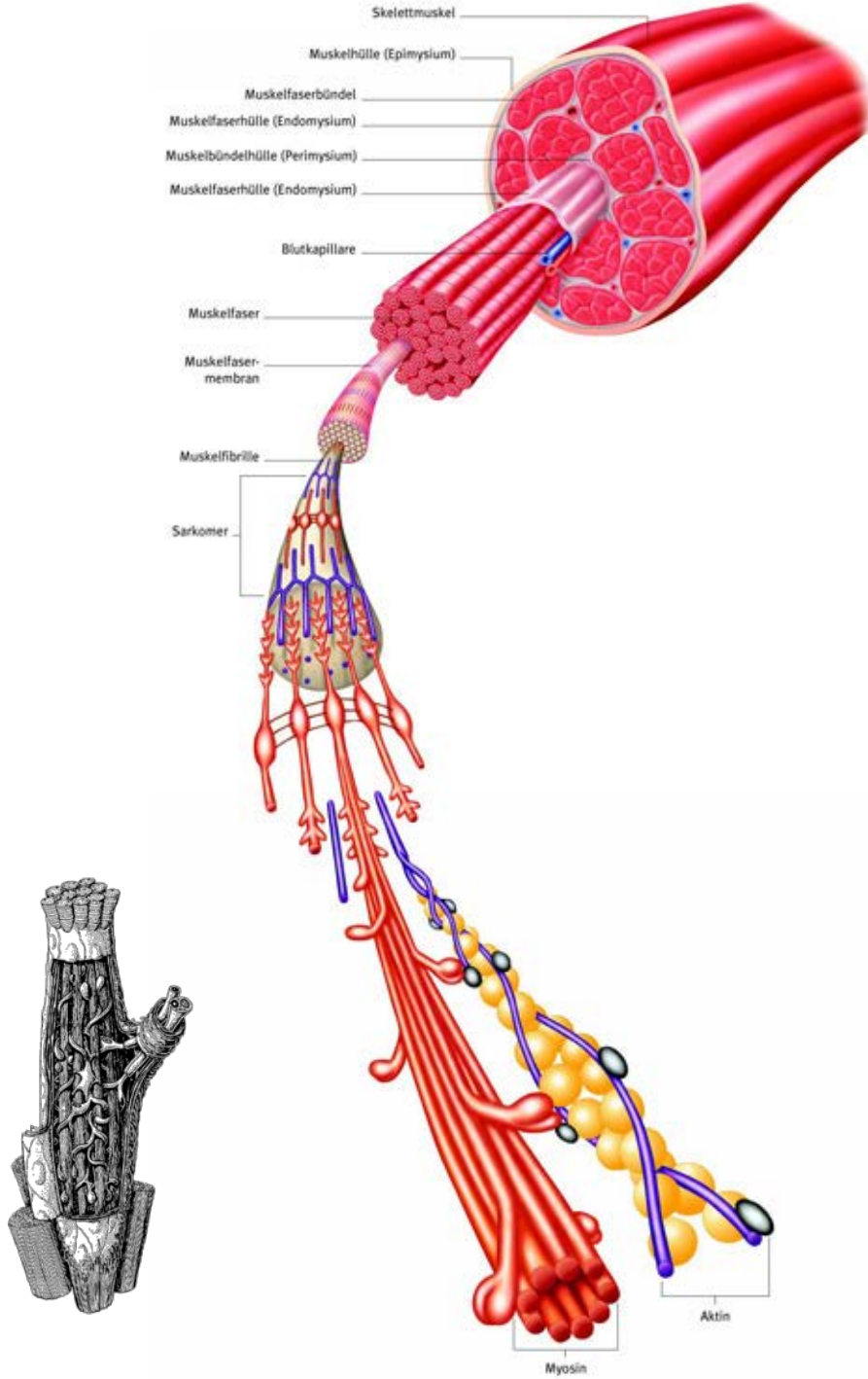
2006/05/01

Wainright SA et al. J Clin Endocrinol Metab 2005;90:2787-93



# Fall risk assessment: diagnosis of independent fall risk factors

- Screening:
  - falls in the previous year / fear of falling
- Muscle power lower extremities (chair rising)
- Balance sideways (tandem maneuvers)
- Vision impairment
- Polypharmacy ( $> 4$ )
- Cognitive impairment
- Creatinine clearance, i.e. renal function



men:

40 % of body weight

women:

30 % of body weight

Daily 1,2 % turn over

Irwin Rosenberg coined the term sarcopenia in 1989, in order to direct the attention to the age-associated decline of muscle mass: Sarx (greek) = flesh, muscle  
Penia (greek)= loss

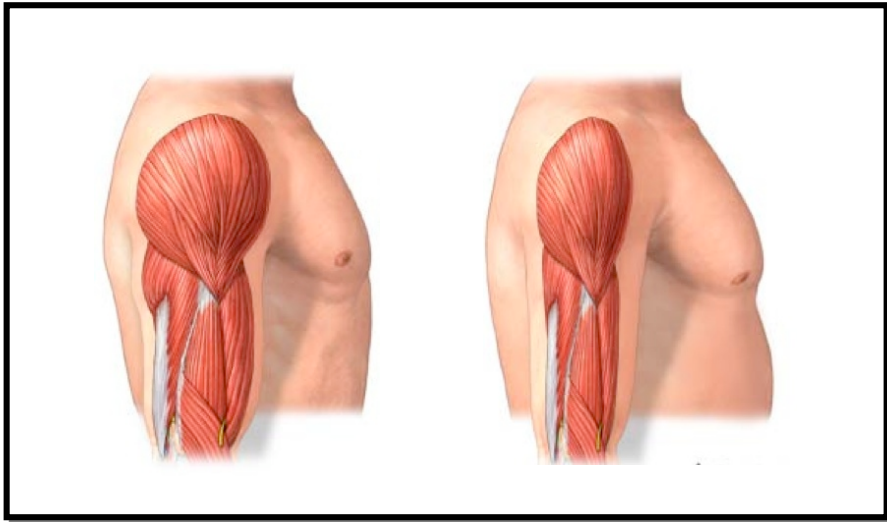
A sort of plea (Rosenberg)  
„No decline with age is more dramatic or potentially more functionally significant than the decline in lean body mass.“

In the evolution of sarcopenia research extensions of the term „sarcopenia“ to muscle structure and muscle function resp. muscle strength have emerged.

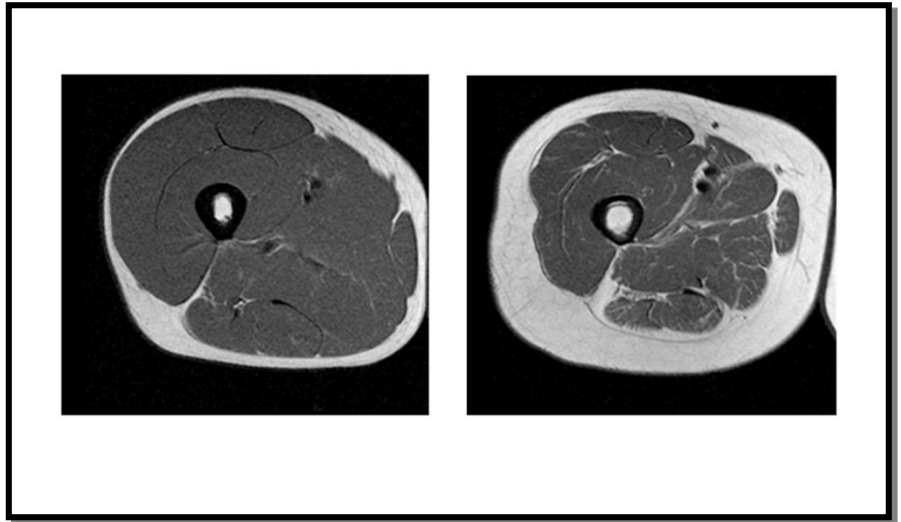
Irwin H. Rosenberg (1989) Summery comments. Am J Clin Nutr. 50:1231-3  
Irwin H. Rosenberg (1997) Sarcopenia: Origins and Clinical Relevance. J. Nutr. 127: 990S–991S, 1997.

# Sarcopenia:

Change of mass, function, material properties, and muscle composition !



Age: 25 years    Age: 65 years



Age: 25 years    Age: 65 years

**Myosteatorsis: infiltration of the aging muscle by fat, inter- and intracellular**

In the current discussion **sarcopenia** does not only include mass, but also

1) changes of muscle composition resp. material properties,

2) **decline of muscle functions (unfortunately measured in very different ways).**

# Sarcopenia is the background of osteoporosis, falls, fractures



(de)conditioned



frail



falls & fractures



disabled



dead

...a gradual process





Ageing is different

Mrs. E., 88 years old,  
performing a strength test.

Arising from a chair (45 cm)  
with one leg without using her  
arms.



Etching

Old Beggar

Rembrandt van Rijn,  
1646

Courtesy of the owner  
(MR)

Muscle atrophy of the hand,  
described by MacDonald Critchley  
as sign of old age.

We are beggars without muscles.  
MR

Shrinking of muscles with age is an  
observation, that belongs to the  
general knowledge of mankind since  
centuries

Muscle contractions are closely linked with the insulin/ glucose and fat metabolism, thus with cardiovascular aging.

Physical activity is associated with a reduction of cardiovascular and all-cause mortality of

**35 % resp. 33 %**

Lifestyle modification (diet and moderate physical activity) reduces 58 % risk of t2Diabetes, compared to 31% by metformin.

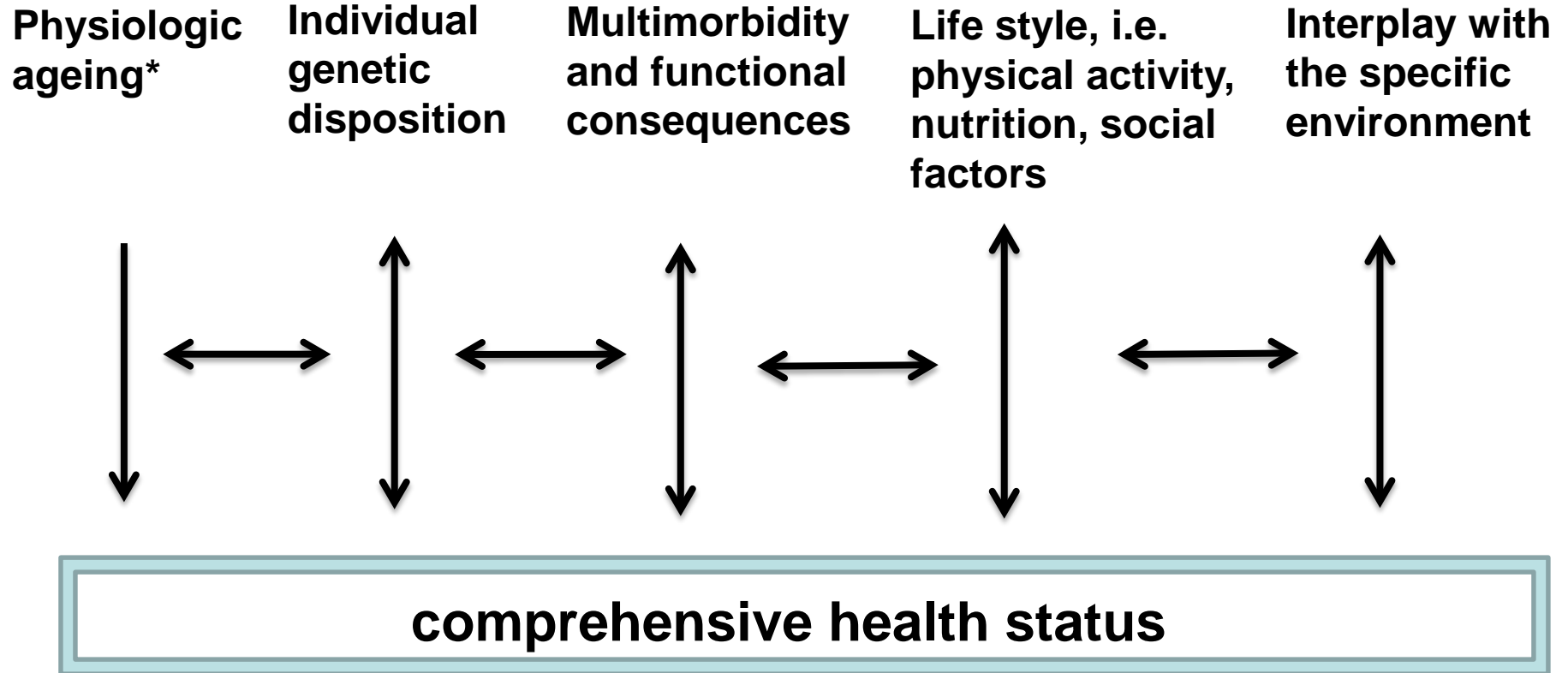
# Diagnosing the „phenotype of frailty“ by Fried’s criteria (Fried et al J of Gerontology, 2001)

- ✓ unintended weight loss ( $> 5$  kg previous year)
- ✓ muscle weakness (lowest 20 % of grip strength)
- ✓ Self-report of exhaustion/ poor endurance
- ✓ impaired walking (lowest 20%, e.g.  $< 0,8$  m/s)
- ✓ low physical activity (lowest 20 % kcal/week)

3 or more criteria: frailty phenotype

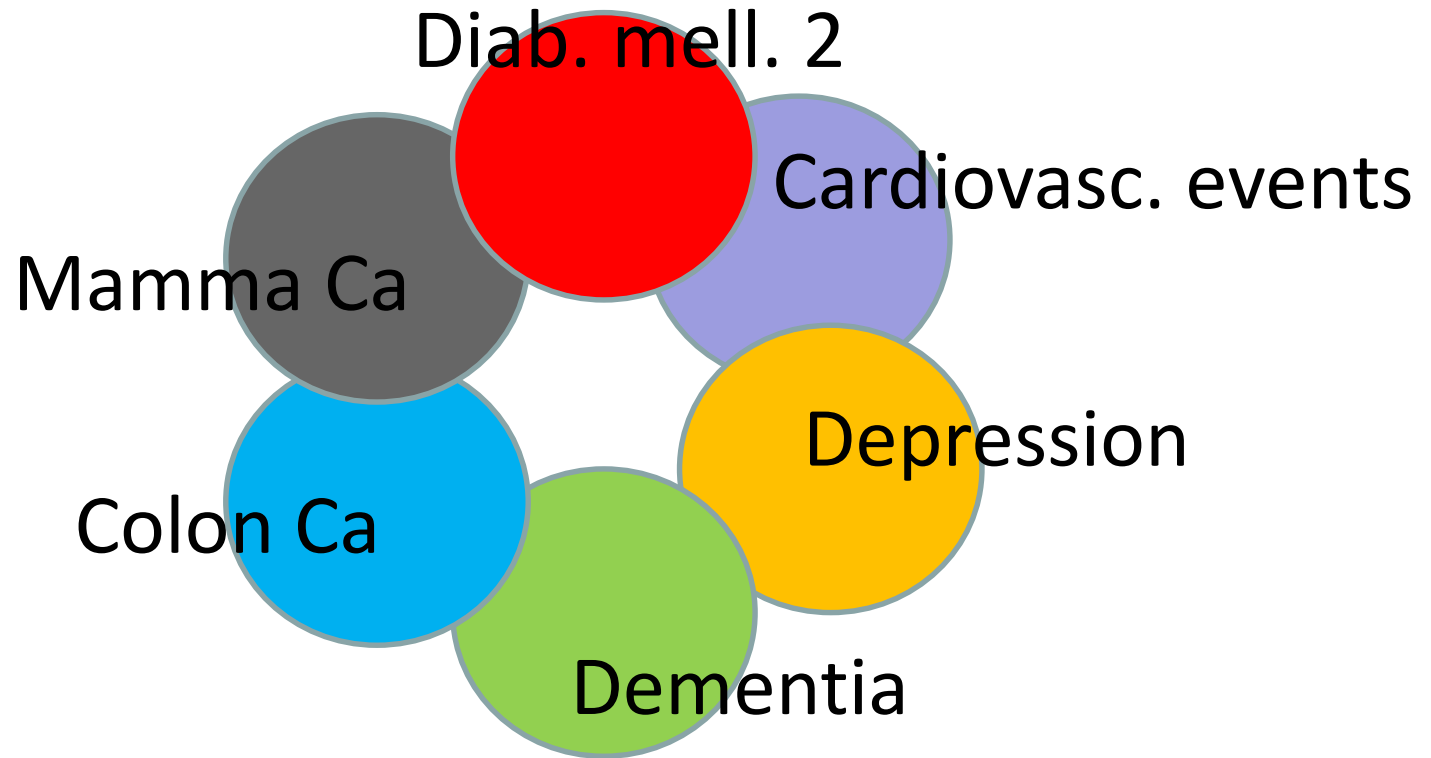
1-2 criteria: prefrail

# The health status in old age is the combined result of the interplay of:



- Ageing = inevitable, concerning every individual, irreversible.

# Diseasome of Physical Inactivity (Bente Pedersen)



Pedersen, B. K. (2009). The diseasome of physical inactivity and the role of myokines in muscle fat cross talk.

*The Journal of Physiology*, 587(23), 5559-5568.

# Diseasome „physical inactivity“ (B. Pedersen 2009)

Physical Inactivity



viszeral fat accumulation



Chron. (subclin.) inflammation/ cytokines



Insuline resistence/ atherosklerosis/  
neurodegeneration/ malignom growth



Diab. mell. 2 / cardiovascular events/ dementia/  
depression/ Colon-Ca/ Mamma-Ca

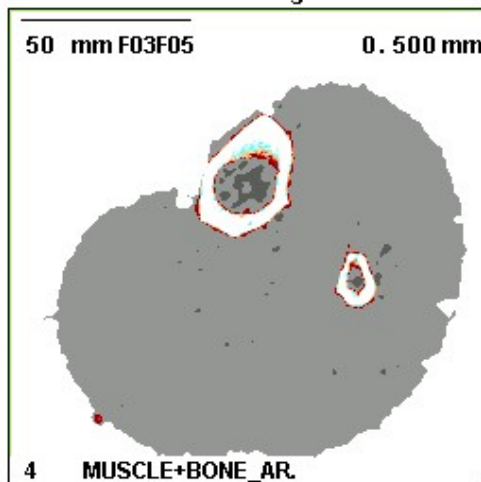
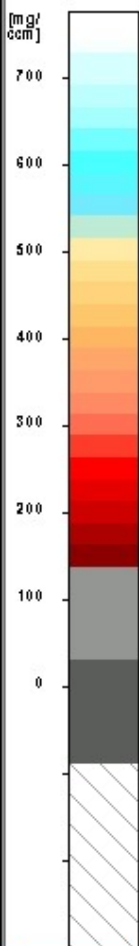




Name                      IT Schnitt 4/6  
 CT Nr.                      Pat.#:20040; 190p5  
 Geb. : 18.07.1949

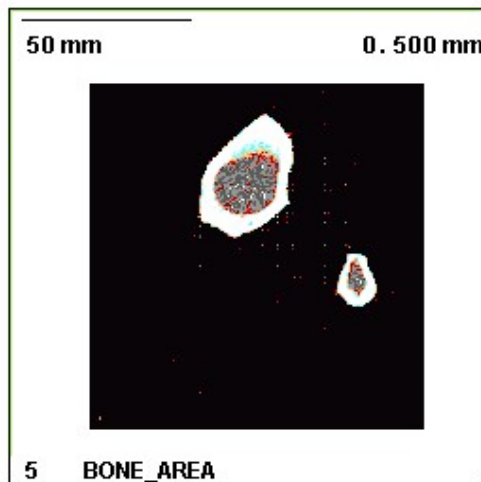
Objectlänge : 340.0 mm männlich  
 Scandatum : 28.10.2002 Alter: 53

Bilder sind nicht für diagnostische Zwecke



MUSCLE+BONE\_AR 66.00 %  
 CBD C3/P1 Th 48 A% 100

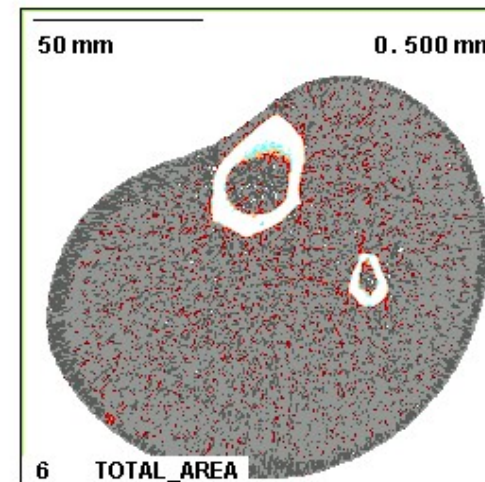
**Gesamt Fläche1** 9805.25 mm<sup>2</sup>  
**Muskel Dichte** 72.24 mg/cm<sup>3</sup>  
**Muskel Fläche** 8935.50 mm<sup>2</sup>  
**Fett Fläche** 1764.50 mm<sup>2</sup>



BONE\_AREA 66.00 %  
 CBD C1/P2 Th 280 100 A% -  
 CORT C1 Th 711

**Masse2** 5.27 g/cm  
**Gesamt Fläche2** 869.75 mm<sup>2</sup>  
**Cort. Dichte2** 1057.73 mg/cm<sup>3</sup>  
**Cort. Fläche2 (=Knochen Fläche)** 419.25 mm<sup>2</sup>  
**Mark Dichte** 14.67 mg/cm<sup>3</sup>  
**Mark Fläche** 240.50 mm<sup>2</sup>

Modus = Muskel Kontur



TOTAL\_AREA 66.00 %  
 CBD C3/P1 Th -52 A% 100

**Gesamt Fläche3** 11569.75 mm<sup>2</sup>  
**Fett+Muskel Dichte** 65.76 mg/cm<sup>3</sup>  
**Knochen/Muskel Fläche** 4.69 %  
**Fett/Muskel Fläche** 19.75 %

Bruch Last X:v; Y:->

**WEITER** **ESCAPE**

ROI CALCBD CORTBD CONCPEEL HISTO SSI LOOP DICHT  
 MENU / AUSWERTEN / ERGEBNIS

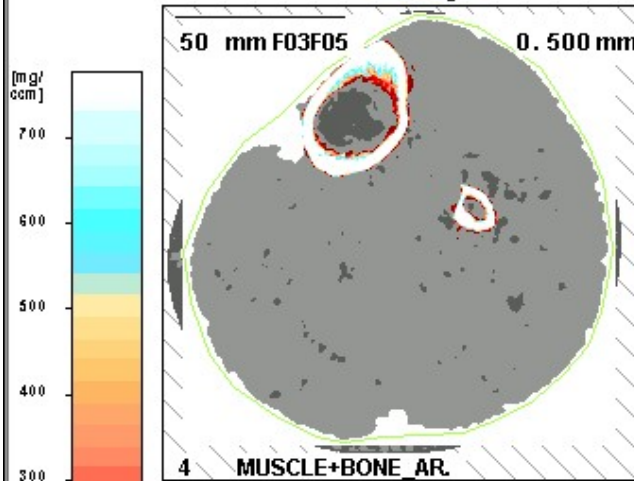
**TABELLE** OK

Used Mem.: 362 [kB] 02.10.2013 18:58

Name                      in  
 CT Nr.                      GHT  
 Geb. : 18.07.1949 Pat.#:20040; 190p5

Objectlänge : 390.0 mm männlich  
 Scandatum : 02.08.2011 Alter: 62

Bilder sind nicht für diagnostische Zwecke



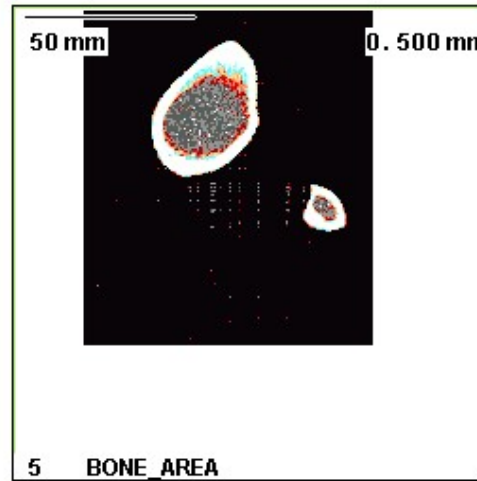
4 MUSCLE+BONE\_AR. 66.00 %  
 CBD C3/P1 Th 40 A% 100

Gesamt Fläche1 11036.25 mm<sup>2</sup>

Muskel Dichte 67.18 mg/cm<sup>3</sup>

Muskel Fläche 9952.00 mm<sup>2</sup>

Fett Fläche 1941.25 mm<sup>2</sup>



5 BONE\_AREA 66.00 %  
 CBD C1/P2 Th 280 100 A% -  
 CORT C1 Th 711

Masse2 5.32 g/cm

Gesamt Fläche2 1084.25 mm<sup>2</sup>

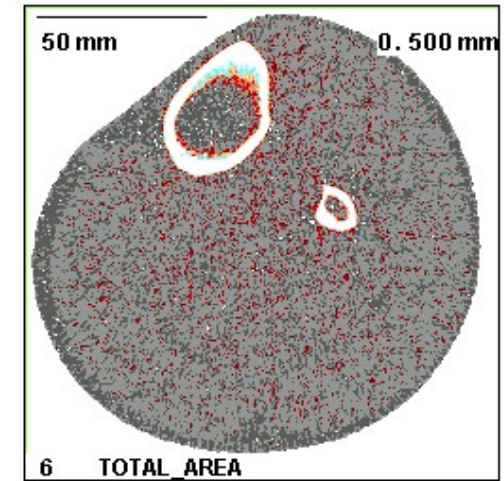
Cort. Dichte2 1064.73 mg/cm<sup>3</sup>

Cort. Fläche2 (=Knochen Fläche) 388.50 mm<sup>2</sup>

Mark Dichte 13.02 mg/cm<sup>3</sup>

Mark Fläche 395.75 mm<sup>2</sup>

Modus = Muskel Kontur



6 TOTAL\_AREA 66.00 %  
 CBD C3/P1 Th -53 A% 100

Gesamt Fläche3 12977.50 mm<sup>2</sup>

Fett+Muskel Dichte 60.44 mg/cm<sup>3</sup>

Knochen/Muskel Fläche 3.90 %

Fett/Muskel Fläche 19.51 %

Bruch Last X:v; Y:-->

WEITER ESCAPE

ROI CALCBD CORTBD CONCPEEL HISTO SSI LOOP DICHT TABELLE OK  
 MENU / AUSWERTEN / ERGEBNIS Used Mem.: 361 [kB] 02.10.2013 19:07

# Established Performance Tests



hand grip strength



habitual gait speed



Chair rising

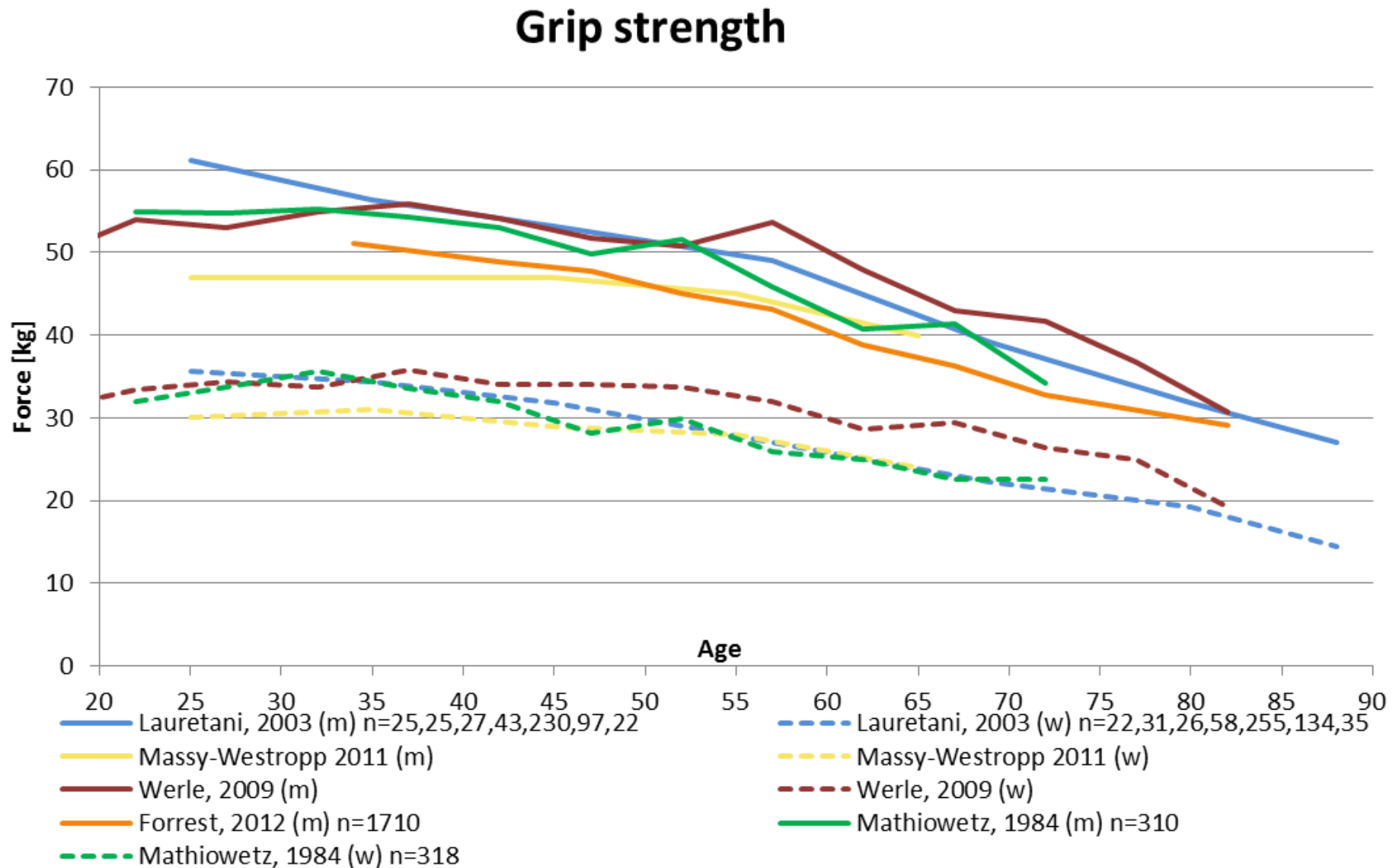


tandem maneuvers



Measuring grip strength: robust predictor of age-related adverse events.

# Grip strength represents general muscle strength and declines with age (cf. sarcopenia)



# How quick is the Grim Reaper?



# How quick is the Grim Reaper?



The grim reaper has (mostly) a walking speed below 0,8 m/s. If we lose our muscle mass and performance with age, = sarcopenia, and become slower.....

Beside of grip strength gait speed is the best single parameter to predict mortality and disability.

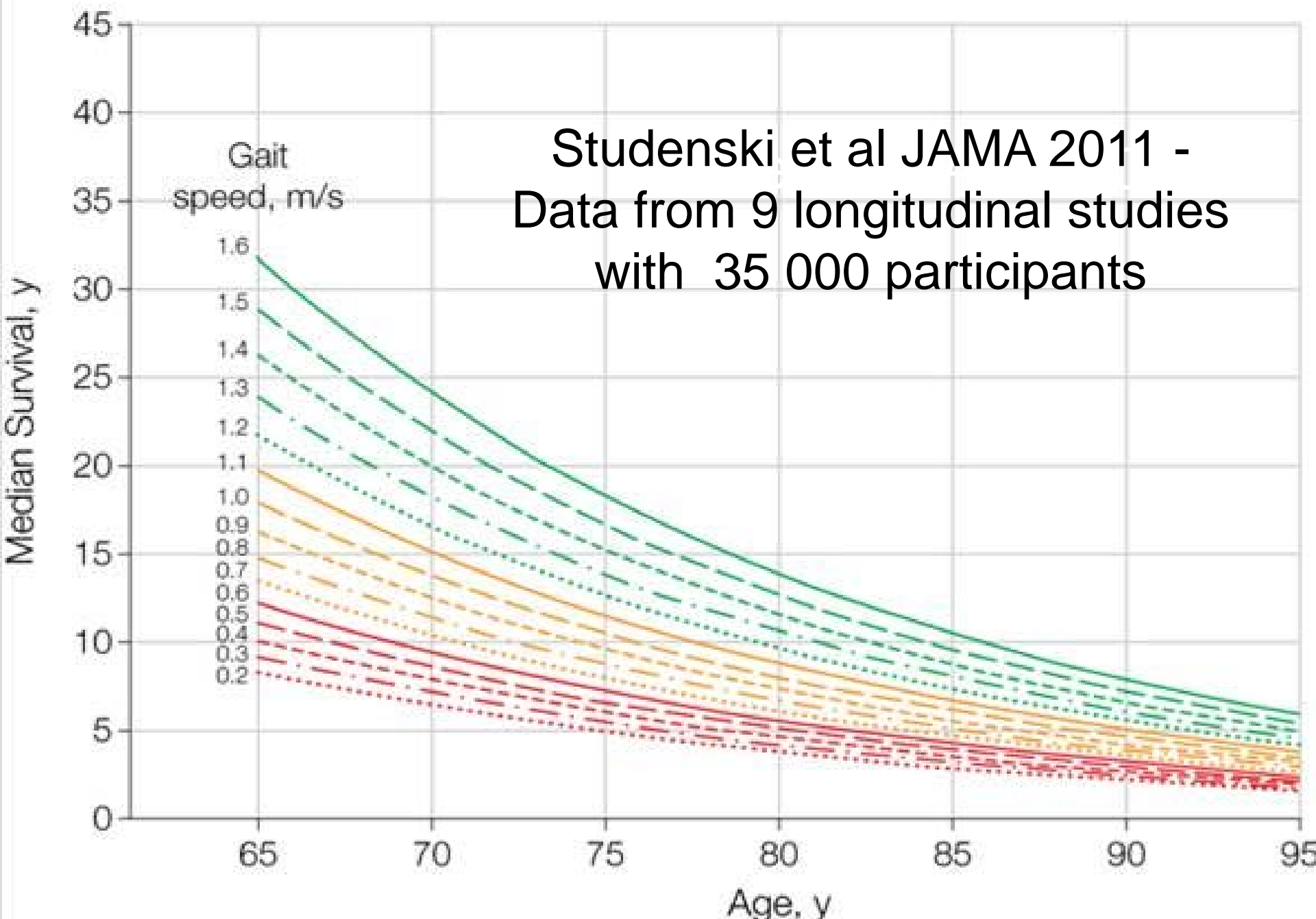


Speed of movement is the sign of vitality.



# Men

Studenski et al JAMA 2011 -  
Data from 9 longitudinal studies  
with 35 000 participants





Chair rising

(Guralnik et al 1994  
and 1995)

5 times rising

from a chair without  
using one's arms:

quicker than

10 seconds

Tandem  
standing:

Less than 10 s

= high fall risk

Tandem walking

more than 8  
steps = half the  
age-related fall  
risk



Fig 2



# Short Physical Performance Battery

(Guralnik et al 1995)

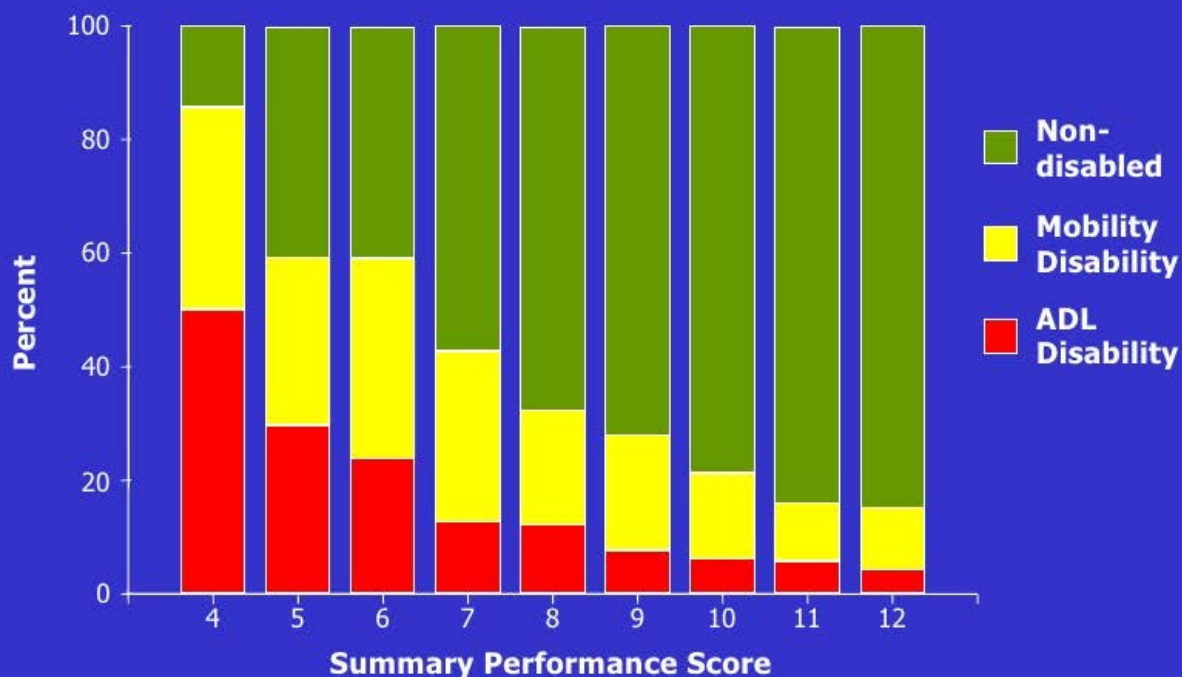
- Self selected gait velocity
- Chair rising
- Romberg – semitandem –tandem standing

Sample categorized into quartiles:

4, 3, 2, 1, 0 points

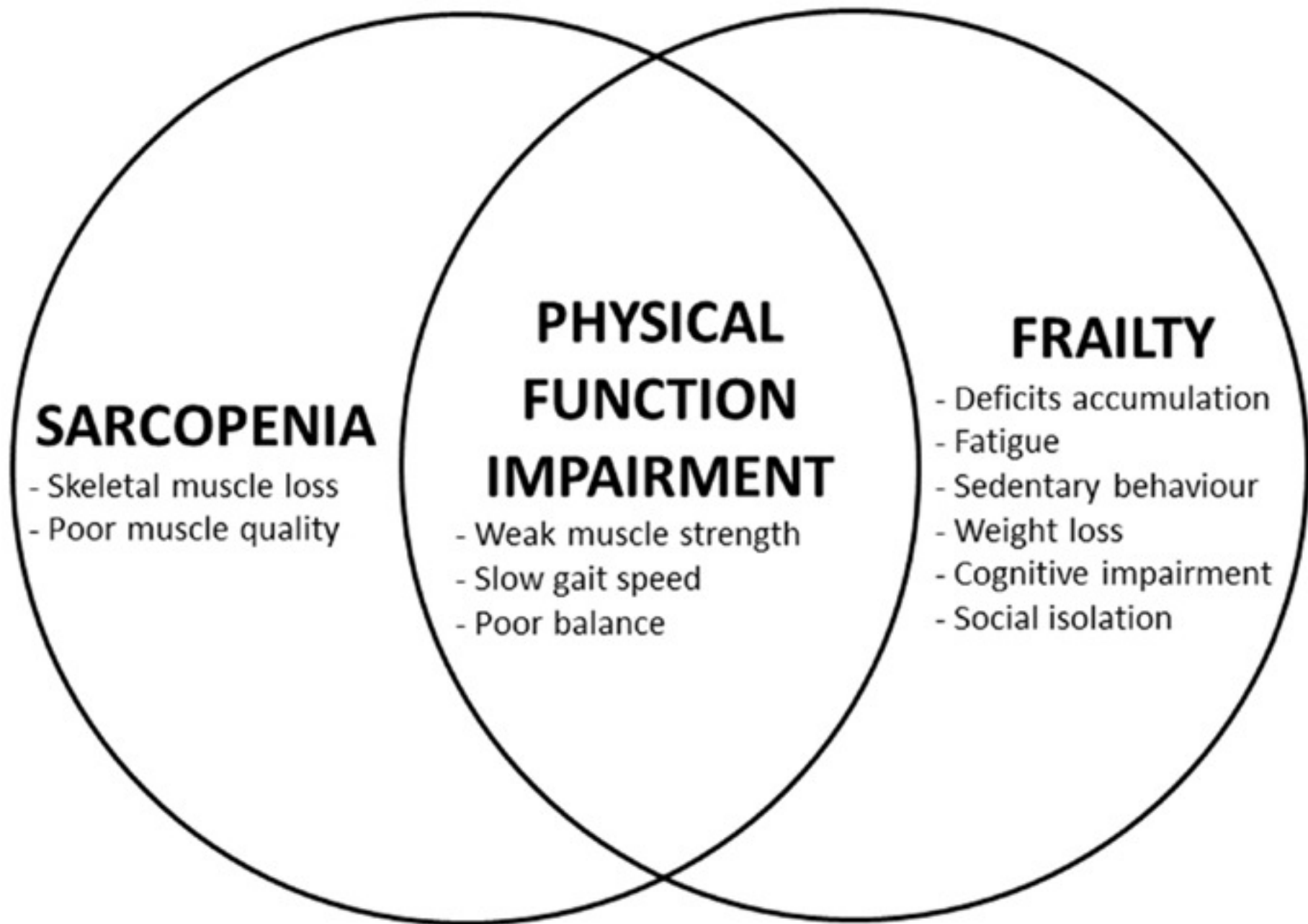
# Guralnik et al 1995: SPPB /Short Physical Performance Battery

**Disability Status at Four Years According to Baseline Summary Performance Score Among Those Non-Disabled at Baseline  
Iowa EPESE**



Source: Guralnik et al. *N Engl J Med* 1995;332:556-561.





## **SARCOPENIA**

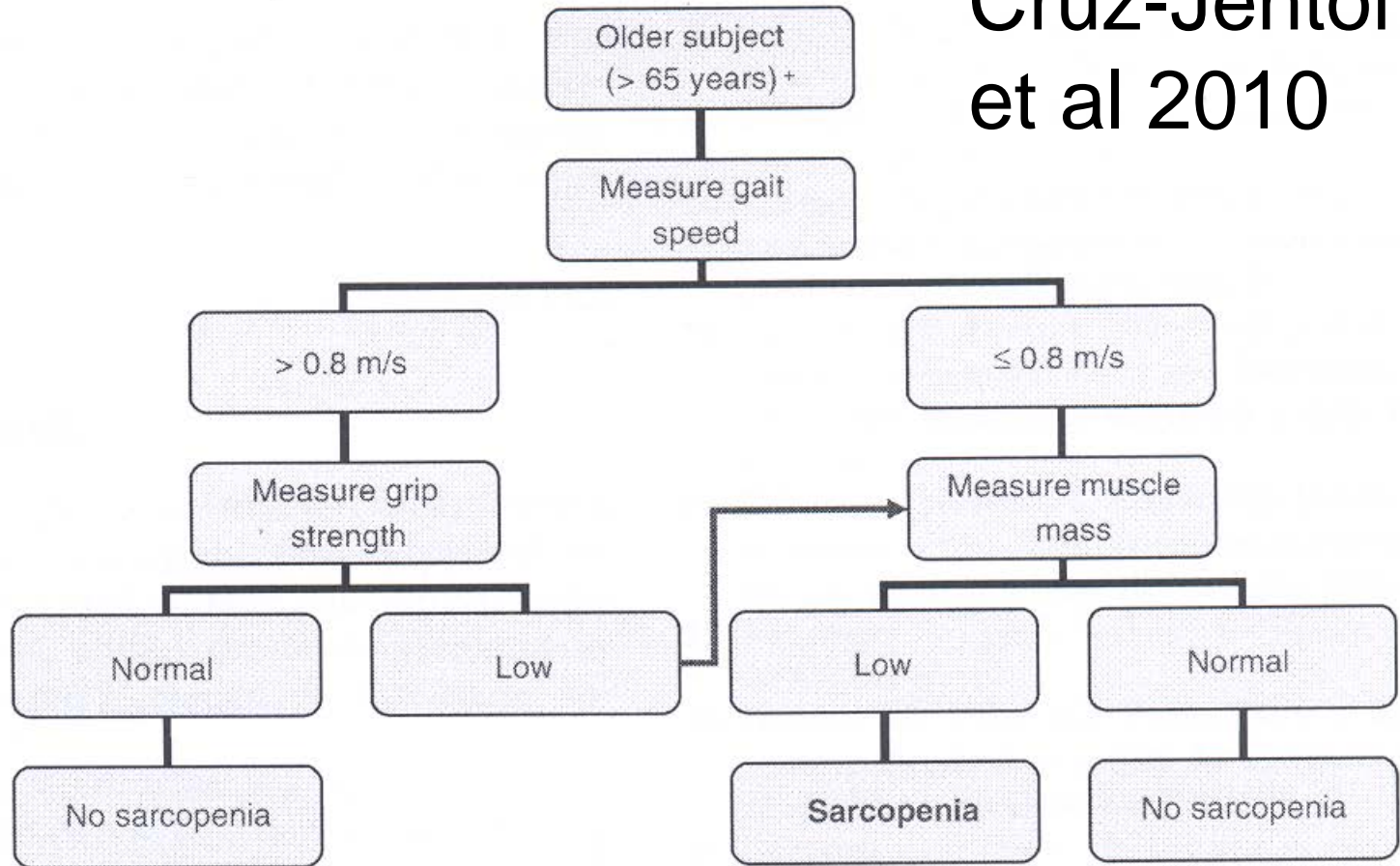
- Skeletal muscle loss
- Poor muscle quality

## **PHYSICAL FUNCTION IMPAIRMENT**

- Weak muscle strength
- Slow gait speed
- Poor balance

## **FRAILTY**

- Deficits accumulation
- Fatigue
- Sedentary behaviour
- Weight loss
- Cognitive impairment
- Social isolation



\* Comorbidity and individual circumstances that may explain each finding must be considered

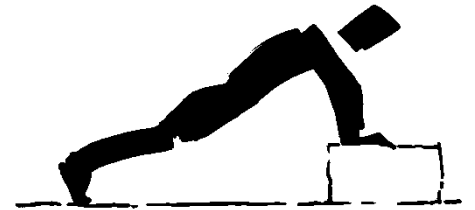
+ This algorithm can also be applied to younger individuals at risk

**Figure 2.** EWGSOP-suggested algorithm for sarcopenia case finding in older individuals.





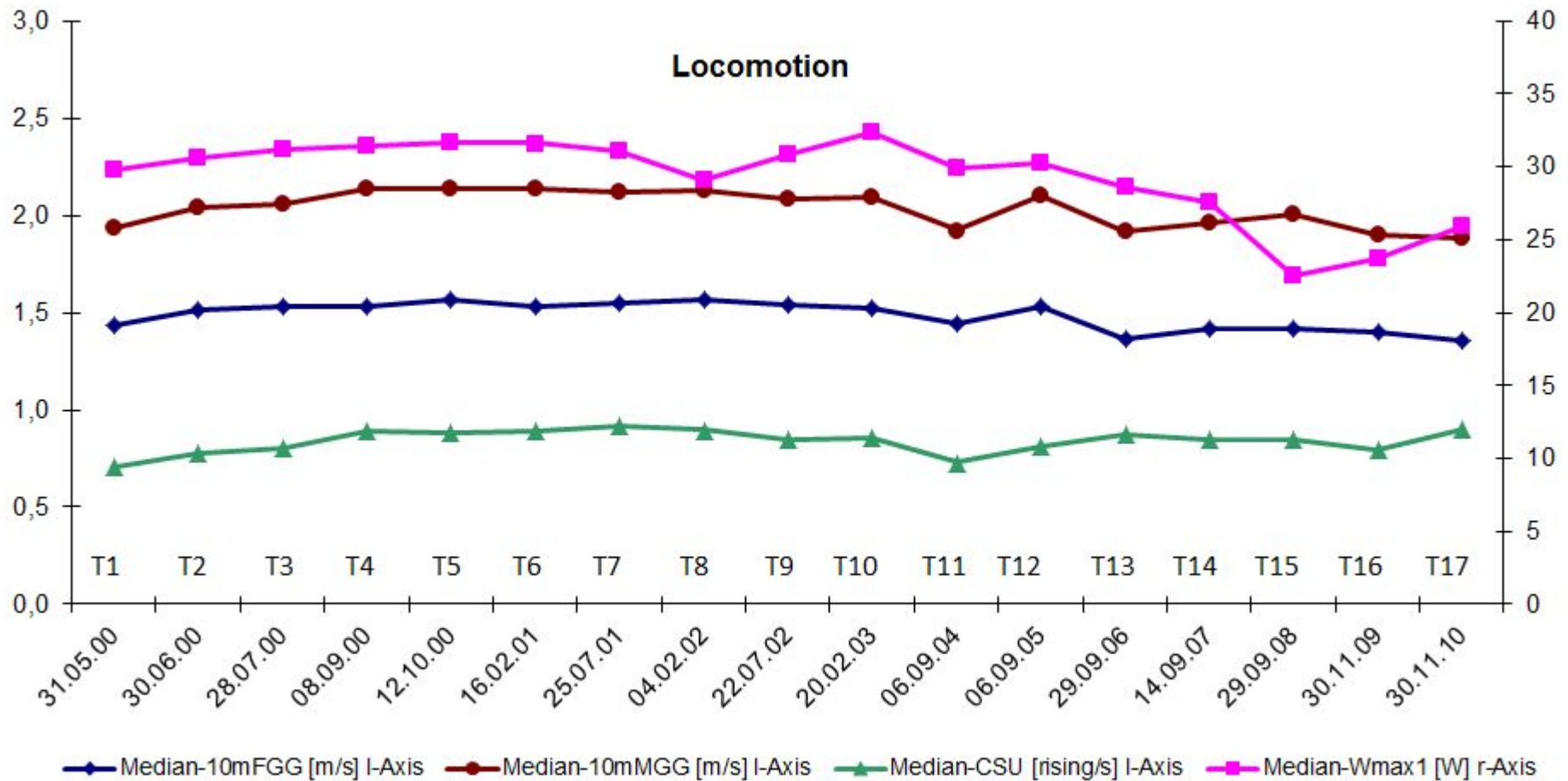
Martin Runge  
Aerпах-Kliniken Esslingen-Kennenburg  
Die „Fünf Esslinger“



[www.fuenfessleringer.de](http://www.fuenfessleringer.de)

# Lokomotor Assessment, 10 year follow-up

ELAN-Study, n=47 mean values of 47 participants /62



Thank you for your attention!  
And.....keep on your feet!

