



EMG & Ultrasound workshop

Xin He

Sports

What is EMG?

- EMG stands for **Electromyography**
- It measures the electrical activity produced when muscles contract.
- Study muscle timing, coordination, and fatigue.
- Surface EMG-non-invasive → most common

Sports

How is sEMG used?

- Electrodes are **placed** on the skin over the target muscle.
- Perform a **motion task** such as running, jumping, squatting, or lifting.
- The EMG signal is **recorded** during the task.
- **Analyse** EMG data to compare technique, muscle recruitment, or rehabilitation outcomes

How is sEMG used?

1. Sensor and electrode selection



2. Skin preparation



3. Sensor location

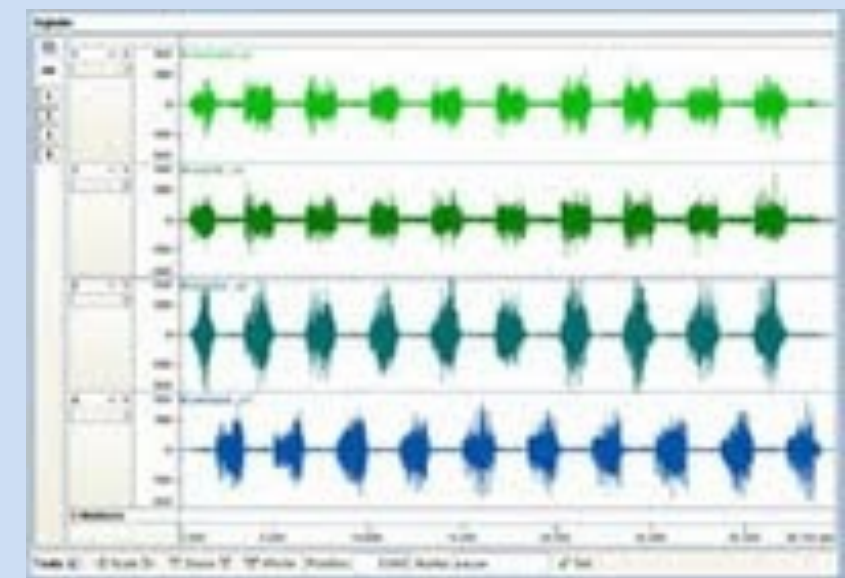


<http://www.seniam.org/>

4. Sensor placement & fixation



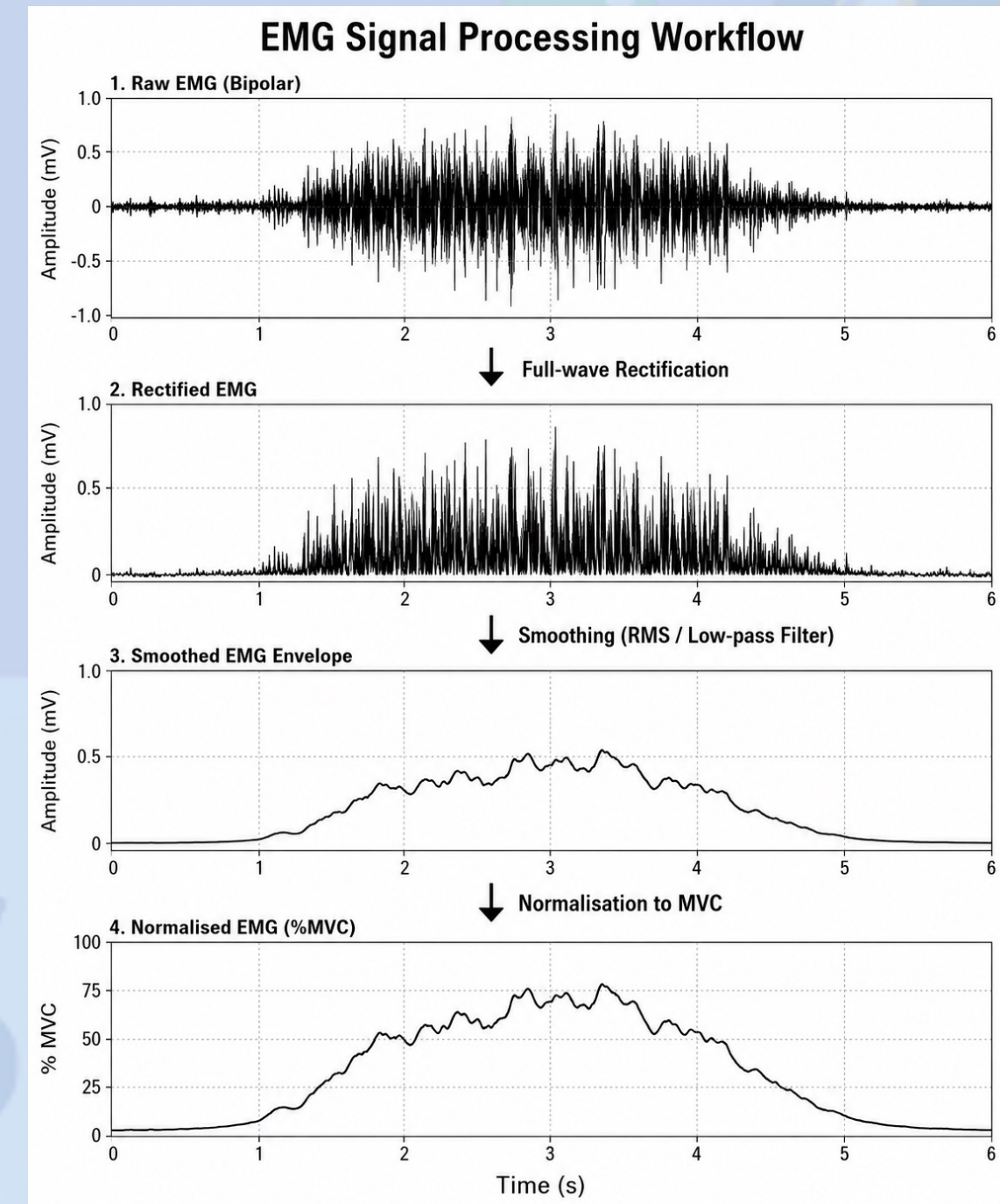
5. Connection testing and recording



How EMG Data is Analysed

Raw EMG signal:

1. Rectified and smoothed (RMS or linear envelope)
2. Normalisation
3. Further calculation: co-contraction ratio, onset time etc.



EMG normalization

Methods: %

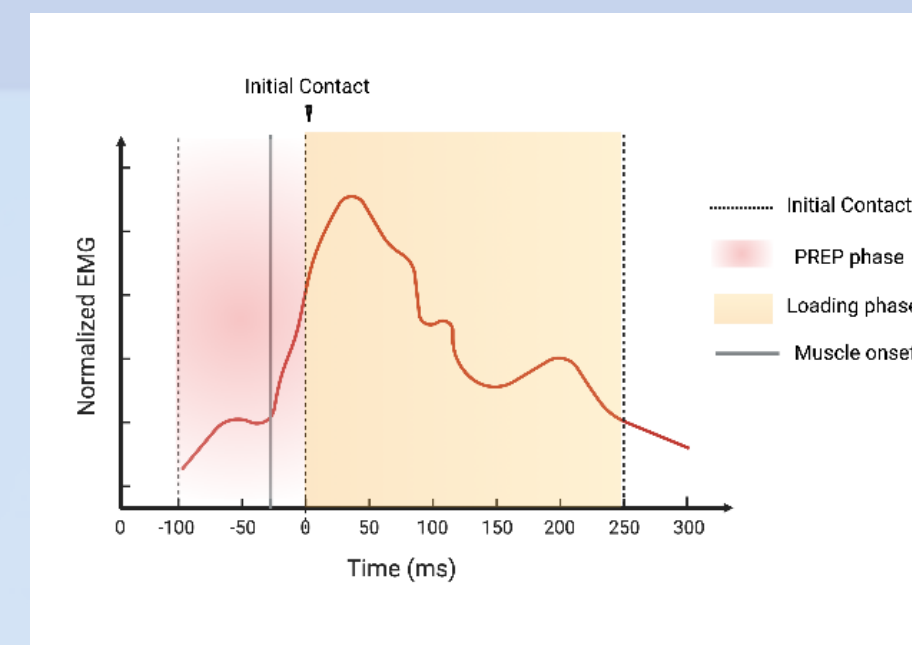
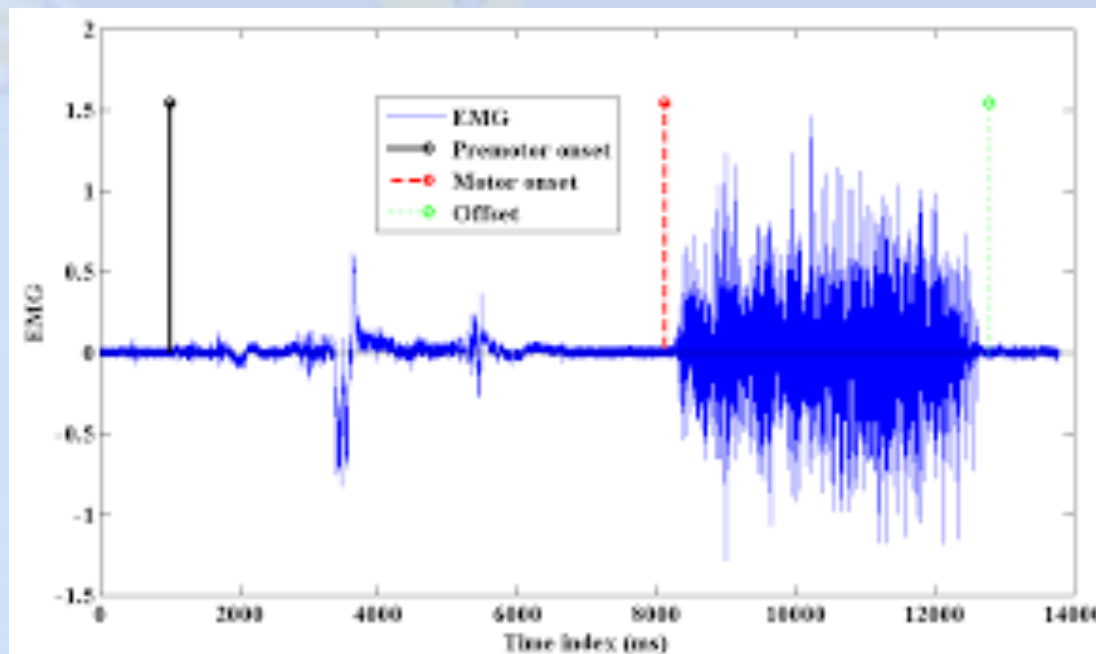
1. **Isometric maximal voluntary contraction**
2. Submaximal reference contraction (eg. 50% of MVIC, holding a 4kg dumbbell = 8RM)
3. Dynamic task-based normalization: Use peak or mean EMG during a reference dynamic task (e.g. walking, squat)
4. Peak dynamic EMG normalization: Normalize to the highest EMG amplitude observed across the task (eg. gait or sport movements)

How can EMG Data be used

- **Amplitude-**
activation level
(%, how much)

- Timing –
**onset/time to
max activation**

- **Frequency -**
muscle fatigue



EMG application in Muscle Evaluation

Randomized Controlled Trial > BMC Neurol. 2019 Jun 24;19(1):140.

doi: 10.1186/s12883-019-1361-z.

Effect of EMG-biofeedback robotic-assisted body weight supported treadmill training on walking ability and cardiopulmonary function on people with subacute spinal cord injuries – a randomized controlled trial

Eddy Yu Yeung Cheung^{1 2}, Kevin Ka Ki Yu^{1 3}, Rachel Lai Chu Kwan¹, Carmen Ka Man Ng¹, Rosanna Mei Wa Chau², Gladys Lai Ying Cheing^{4 5}

JAT JOURNAL OF ATHLETIC TRAINING

J Athl Train. 2015 Jul; 50(7): 697–703.

doi: [10.4085/1062-6050-50.4.05](https://doi.org/10.4085/1062-6050-50.4.05)

PMCID: PMC4532180

PMID: [26067429](https://pubmed.ncbi.nlm.nih.gov/26067429/)

Muscle Reaction Time During a Simulated Lateral Ankle Sprain After Wet-Ice Application or Cold-Water Immersion

Peter K. Thain, PhD,^{*} Christopher M. Bleakley, PhD,[†] and Andrew C. S. Mitchell, PhD[‡]

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SCANDINAVIAN JOURNAL OF MEDICINE & SCIENCE IN SPORTS

ORIGINAL ARTICLE | [Full Access](#)

Effects of football simulated fatigue on neuromuscular function and whole-body response to disturbances in balance

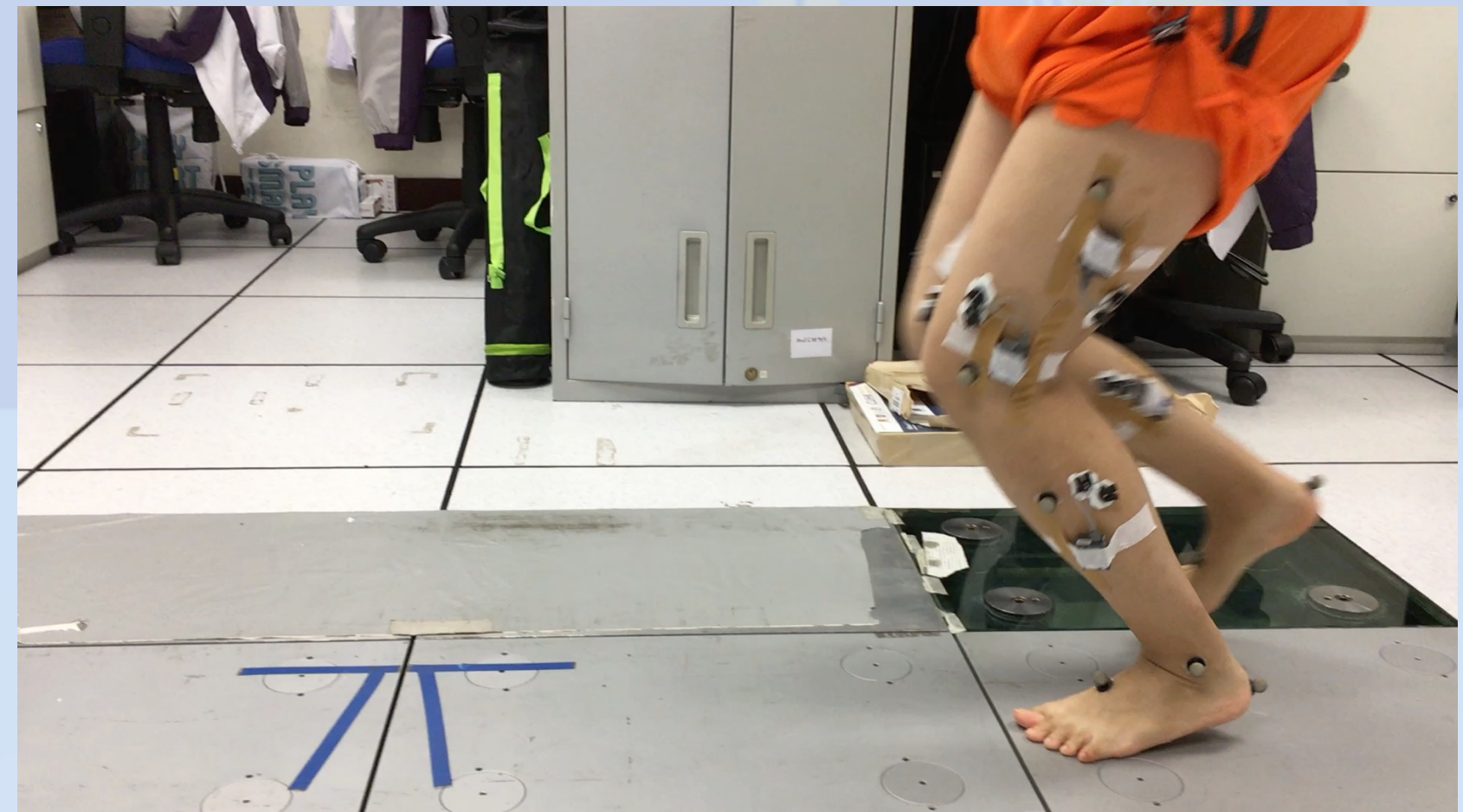
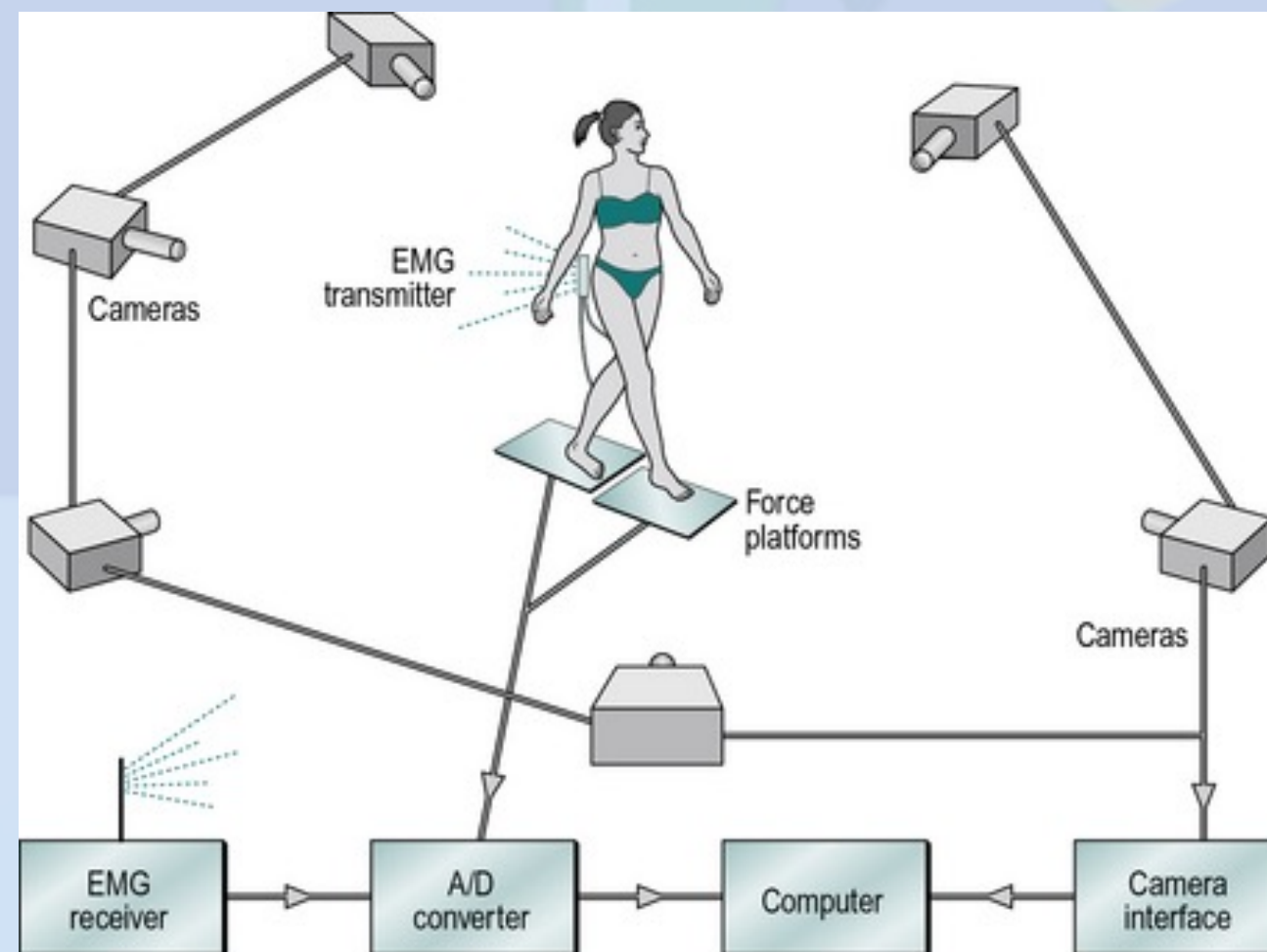
Fearghal P. Behan✉, Scott Willis, Matt T.G. Pain, Jonathan P. Folland,

Applications:

To evaluate

- Muscle contraction level
- Muscle co-contraction
- Muscle reaction time
- Muscle fatigue
- EMG-biofeedback robotic-assisted

Motion analysis synchronized with EMG



Limitation of EMG

- **Not a direct measure of force:** relates to neural drive, but the EMG–force relationship is nonlinear
- **Strong sensitivity to recording conditions:** influenced by electrode placement, orientation, skin preparation, subcutaneous fat, skin–electrode impedance, and movement artefact
- **Crosstalk from neighbouring muscles:** esp small and deep muscles
- Between-session and between-subject **variability**

What is Ultrasound?

- Ultrasound uses high-frequency sound waves to create images of body tissues.

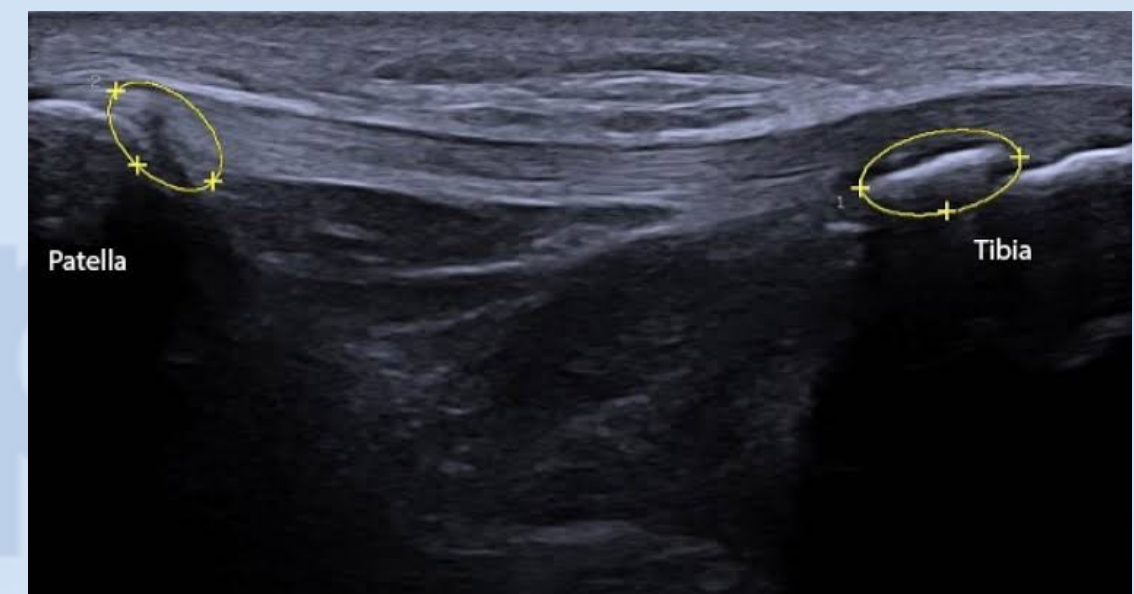
Probe (**transducer**) sends sound waves into the body



Sound waves travel through tissue and reflect differently depending on tissue density and composition.



Converts those echoes into a grey-scale image.



Different probes and frequency



Frequency: Expressed in Megahertz (MHz)

High frequency: Greater resolution, shallow penetration (attenuation), best for more superficial structures

Low frequency: Lower resolution, greater penetration, good for deeper structures

How to differentiate tissues

- **Bone/calcification:** very bright or hyperechoic, with a dark shadow behind it
- **Fluid:** black or anechoic, often with posterior acoustic enhancement
- **Tendon:** bright, fibrillar, and very organized in long-axis view
- **Muscle:** darker or hypoechoic with internal bright lines
- **Fat:** usually intermediate to bright depending on depth and location
- **Nerve:** honeycomb pattern in short-axis view



Shear wave elastography



Shear wave elastography (SWE) is valid and reliable to measure tissue stiffness in a quantitative manner.

(Eby S F et al, 2013)

Imaging Physics

Free

Shear-Wave Elastography: Basic Physics and Musculoskeletal Applications

Mihra S. Taljanovic , Lana H. Gimber, Giles W. Becker, L. Daniel Latt, Andrea S. Klauser, David M. Melville, Liang Gao, Russell S. Witte

ULTRASONOGRAPHY

<http://www.e-ultrasonography.org/>

This Article

Aims and Scope

Instructions for Authors

e-Submission

[Ultrasonography](#). 2019 Jan; 38(1): 2–12.

Published online 2018 Aug 23. doi: [10.14366/usg.18039](https://doi.org/10.14366/usg.18039)

PMCID: PMC6323314

PMID: [30343557](https://pubmed.ncbi.nlm.nih.gov/30343557/)

Clinical utilization of shear wave elastography in the musculoskeletal system

[Leah C. Davis](#),^{1,2} [Timothy G. Baumer](#),³ [Michael J. Bey](#),³ and [Marnix van Holsbeeck](#)²

Shear wave elastography

Shear waves are generated from a linear US array



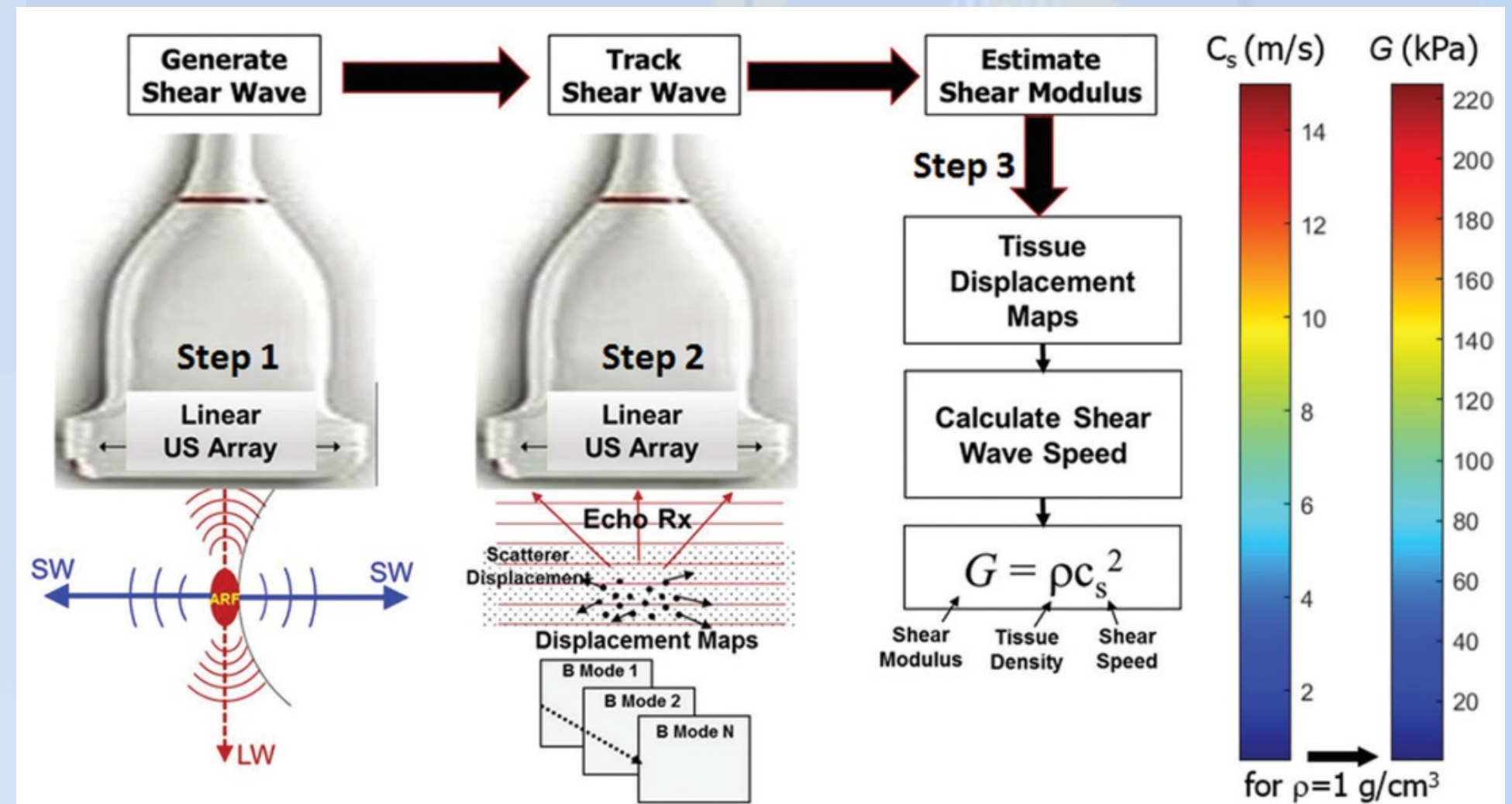
Provides a local stress and generates local displacement in the tissue



Detection of the propagation of the induced shear waves

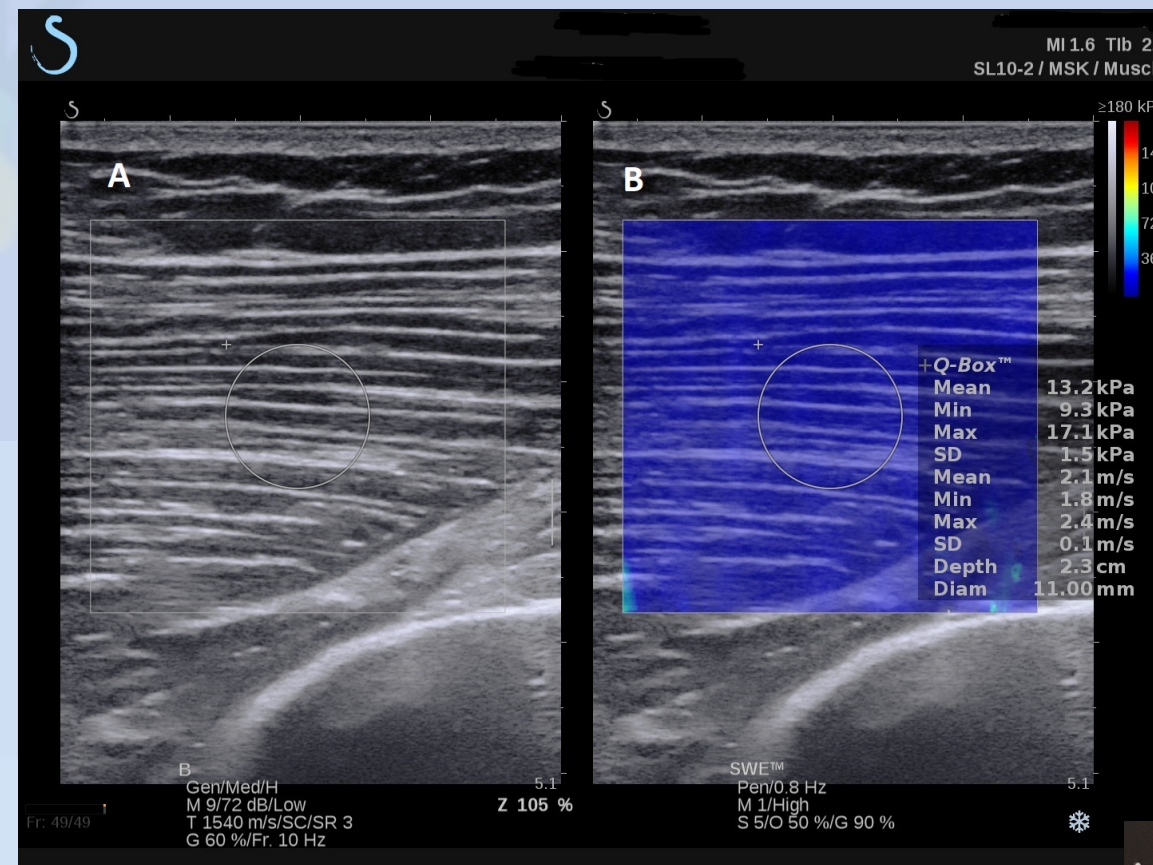


Processing of the shear waves to create elastograms



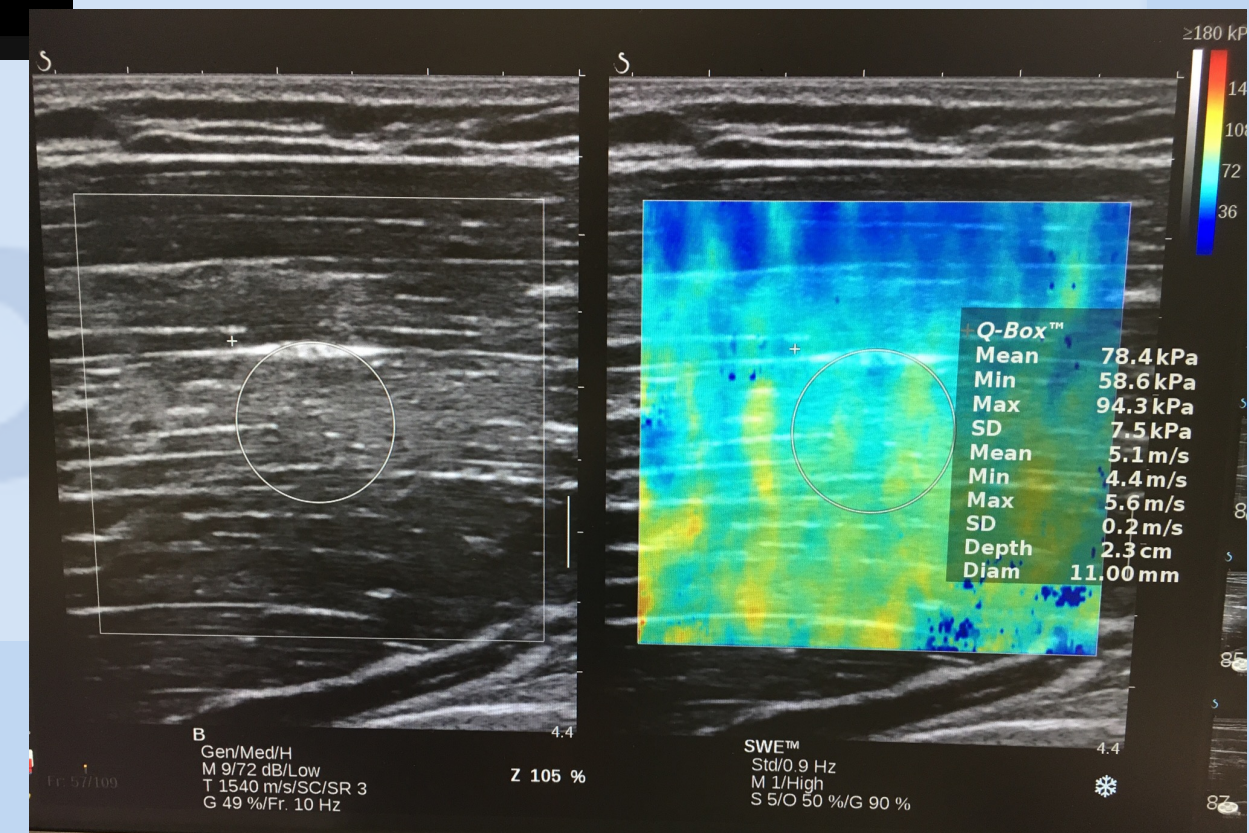
Shear wave elastography

Shear waves propagate faster in stiffer and contracted tissues and along the long axis of the tissues.



Resting muscle stiffness

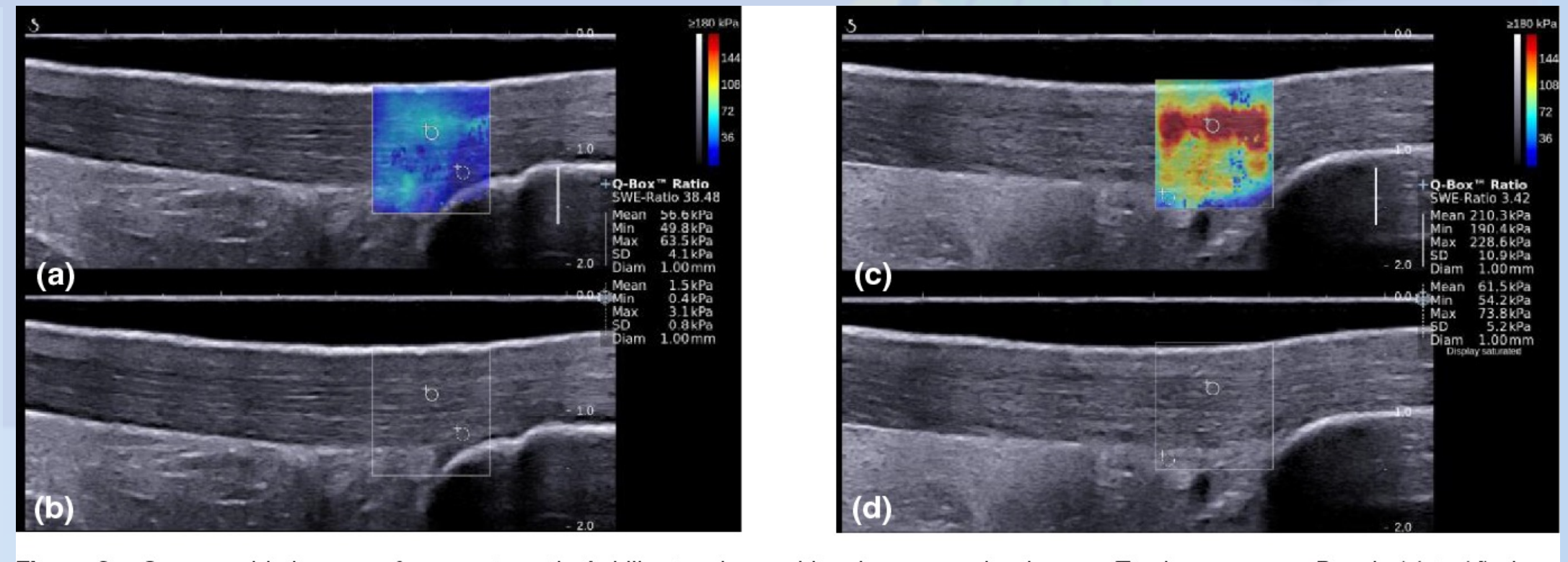
Muscle stiffness during submaximal contraction



Shear wave elastography

Applications:

- Changes in pathological condition (eg. Tendinopathy/tear)
- Before and after intervention (exercise/ stretching/surgery)
- Correlate with function or performance



Sonographic images of a symptomatic Achilles tendon and its changes under therapy

(Dirrichs T et al,2018)

Shear wave elastography studies

Muscle:

- Quadriceps, Hamstring, Soleus,, Gastrocnemius, Tibialis anterior
- Supraspinatus, Biceps brachii,
- Multifidus, lumbar erector spinae,, quadratus lumborum

Tendon:

- Quadriceps tendon
- Achilles tendon

Others:

- Plantar fascia
- Iliotibial band



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Musculoskeletal Science and Practice

journal homepage: www.elsevier.com/locate/msksp

Original article

Lumbar muscle stiffness is different in individuals with low back pain than asymptomatic controls and is associated with pain and disability, but not common physical examination findings^{☆,☆☆}

Shane Koppenhaver^{a,*}, Emily Gaffney^b, Amber Oates^b, Laura Eberle^b, Brian Young^a, Jeffrey Hebert^c, Laurel Proulx^d, Minoru Shinohara^e

Sophie Bastijns^{*,†,✉}, Anne-Marie De Cock^{*,†}, Maurits Vandewoude^{*,†,‡}, Stany



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Decreased passive muscle stiffness of vastus medialis is associated with poorer quadriceps strength and knee function after anterior cruciate ligament reconstruction[☆]

Xin He, Wan Yun Huang, Hio Teng Leong, Ji Hong Qiu, Chun Cheong Ma, Sai-Chuen Fu, Michael Tim-Yun Ong, Patrick Shu-Hang Yung^{*}

Ultrasound application in sports medicine

Diagnosis

- Tendon (tendinopathy, tears)
- Muscle (strains, contusions)
- Nerve (entrapment)
- Ligament (sprains)
- Joint (effusions)

Quantitative assessment

- Muscle thickness/size/volume
- Muscle stiffness
- Muscle pennation angle
- Tendon thickness/ stiffness
- Ligament thickness
- Joint effusion volume

Reliability in measurement

- . Reliability: a measurement gives similar results when repeated under the same conditions
- . To see whether change is real or just measurement error.

Intra-session reliability

intra-operator reliability

Inter-session reliability

inter-operator reliability

Reliability parameters

**intraclass Correlation Coefficient
(ICC)**

- How well repeated measurements agree relative to differences between people.

**Standard Error of Measurement
(SEM)**

- Amount of random error in the same units as the test.

**Minimal Detectable Changes
(MDC)**

- The smallest change likely to be real and not just due to error.

Why reliability is important

- EMG reliability can be affected by electrode placement, skin preparation, movement, and signal processing.
- Ultrasound reliability can be affected by probe position, pressure, angle, and examiner skill.
- **Standardized protocols** improve reliability for both methods.
- Studies show that **careful technique** can produce good to excellent reliability

Time for practice !

Group A,B,C: Ultrasound session

Task:

1. Identify four quadriceps muscles, measure the thickness and cross sectional area of RF
2. Identify medial joint space, MCL, cartilage, patella tendon and Quadriceps tendon

Group D,E,F: EMG session

Task:

1. Try to do skin preparation EMG placement for VM, VL, BF and SM according to SENIAM
<http://www.seniam.org/>
1. Complete the group activities

Quadriceps

