



中山大學 附属第一医院
THE FIRST AFFILIATED HOSPITAL, SUN YAT-SEN UNIVERSITY

运动重建实验及临床转化

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大纲

- 中山一院康复科运动实验室简介
- 超声应用于康复和运动重建的系列研究
- 美国见闻





实验室条件

中山大学 附属第一医院
The First Affiliated Hospital of Sun Yat-sen University

运动重建实验室 Motor Recovery Research Laboratory

运动重建实验室主要从事以运动障碍为主要表现，涉及中枢和外周神经损害、肌肉骨关节本身损伤等表现出来的运动功能障碍检查、评估和康复的研究，同时也包括认知、注意力等方面的康复研究。中山大学附属第一医院康复医学科从上世纪80年代初开始系统的卒中康复系列研究，曾作为主要研究单位参与国家“九五”、“十五”科技攻关课题，包括脑血管病早期康复的研究、脑血管病三级康复治疗方案的研发及脑血管病二级预防与康复的研究等，发表了大量的学术论文。近几年的研究主要是康复干预治疗对运动神经可塑性方面的影响，以及步态三维运动学的量化改变和矫形支具干预的步态分析。前者研究显示康复干预对鼠脑损害模型中的神经可塑性有促进作用，而后者研究得出的偏瘫三维步态运动分析的特征和数字化的动态指标将成为今后功能评定的金标准。

目前运动重建实验室包括研究所需的设备有：

(1) 英国VICON三维运动分析系统 (3D motion evaluation system)：包括6部MX13红外线摄像机，数字式CMOS感应器，130万像素分辨率，每秒1-10,000工作频率，全分辨率最高频率240Hz；64道模拟数字转换器；Vicon Polygon多媒体分析软件和BodyBuilder软件包等。

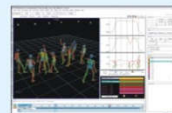
(2) 美国AMT OR6-7测力板：包括2块测力板464×508×83mm；信号放大器等。

(3) 美国Noraxon LLC MyoSystem 1400A表面肌电图机 (sEMG)：包括MS1400A sEMG主机；MS1400A8导Active Cable Set1套；USB接口等。

(4) 美国Visio Trainer 情景互动训练系统

(5) 美国SpinoFlex 脊柱减压升降系统和NORAMCO 运动平板

(6) 美国Microsoft虚拟环境反馈训练系统连屏幕 (Microsoft X-Box 360 Kinect)



VICON 三维运动分析系统



表面肌电系统



NORAMCO 运动平板



SpinoFlex 脊柱减压升降系统



Xbox360虚拟环境反馈训练系统

运动重建实验室在研项目(On-going Projects)包括国家自然科学基金项目2项，中山大学百人计划科研启动项目1项。博士生课题2项，硕士生课题2项。已完成的有国家“九五”、“十五”和“十一五”科技攻关课题和省级科研项目多项。

目前运动重建实验室人员包括：

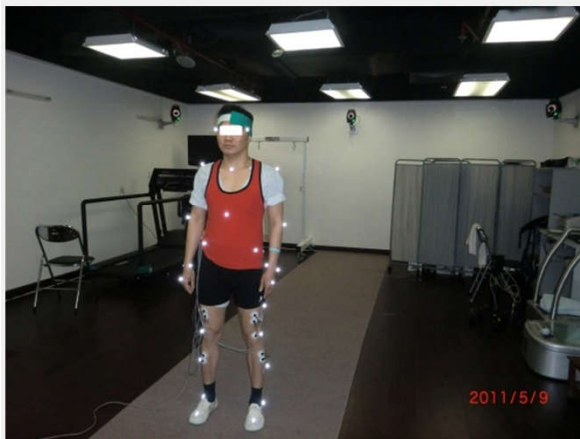
黄东锋 教授 博导 主任医师

毛玉培 副主任治疗师

徐光青 副主任医师 博士

李 乐 副研究员 博士

中山大学附属第一医院康复医学科
<http://www.surweb.org.cn>





History of Rehabilitation Medicine

- ❖ Our department was established in **1982**, one of the **earliest rehabilitation medicine programs** in the hospitals of China.
- ❖ Since 1987, our department has become the collaboration center of rehabilitation with **World Health Organization**.
- ❖ In 2013, our department was granted the **national clinical key discipline** of rehabilitation medicine by Ministry of Health of China.





Clinical Service in Rehabilitation

- Inpatient Unit and Outpatient Unit
- Integrated and well-found rehabilitation service, including:
 - Physical Therapy
 - Occupational Therapy
 - Speech Language Pathology
 - Prosthesis and Orthoses





PT Unit



OT Unit

Clinics



Inpatient Unit



P&O Unit



Research Labs of Rehab. in 1st Hospital, SYSU

●Motor Recovery Research Lab.: Prof. Dongfeng Huang

Faculty Team: Dr. Le Li , Prof. Yurong Mao

●Speech and Hearing in Neuroscience Lab.:

Faculty Team: Prof. Hanjun Liu (Lab-in-charge)

Prof. Peng Liu, Prof. Xi Chen, Ms. Shaozhen Chen





Research interests in Motor recovery

- Mechanisms underlying motor recovery of persons after stroke
- Neuromusculoskeletal modeling combined with in vivo ultrasound measurement
- Muscle Health condition and its mechanism on neuromuscular diseases
- Multisensory intervention and its mechanism evaluation by fMRI for persons after stroke





Evaluation and intervention study on rehab. robot

Motor control relearning
15 sessions conducted five times per week for three weeks

Each one-hour session
included approximately 50'
and brief rest when needed

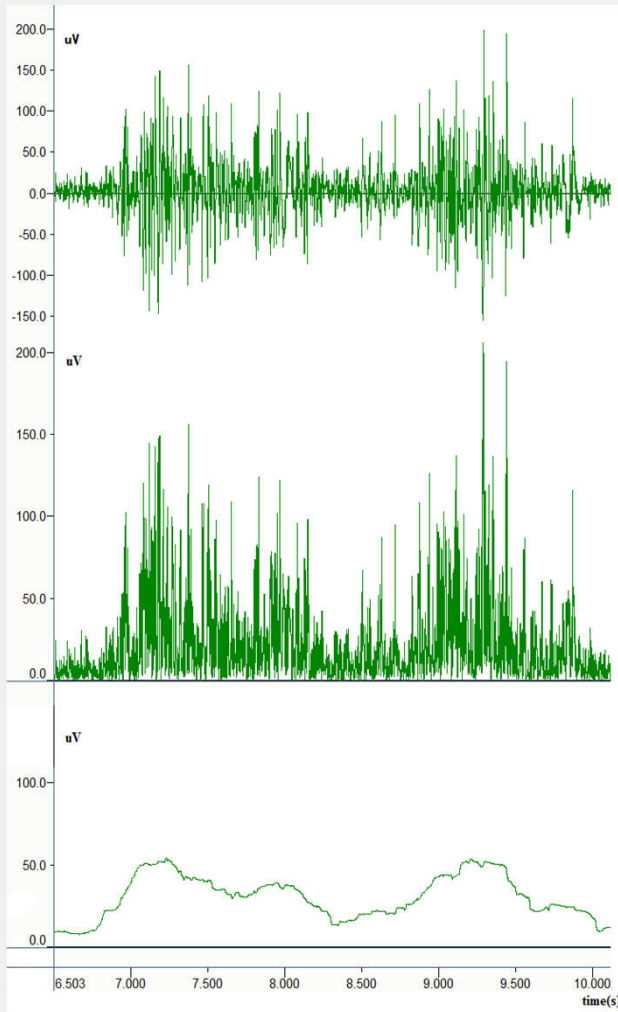
Training program——

- **SIT-TO-ST and TRANSFER**
- **STANDING BALANCE - STATIC and DYNAMIC**
- **UP and DOWN STAIRS**



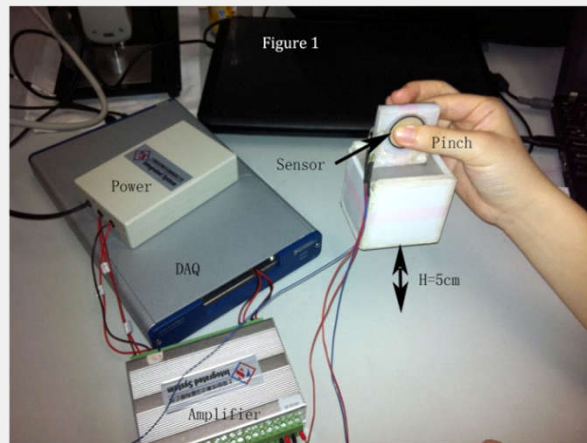
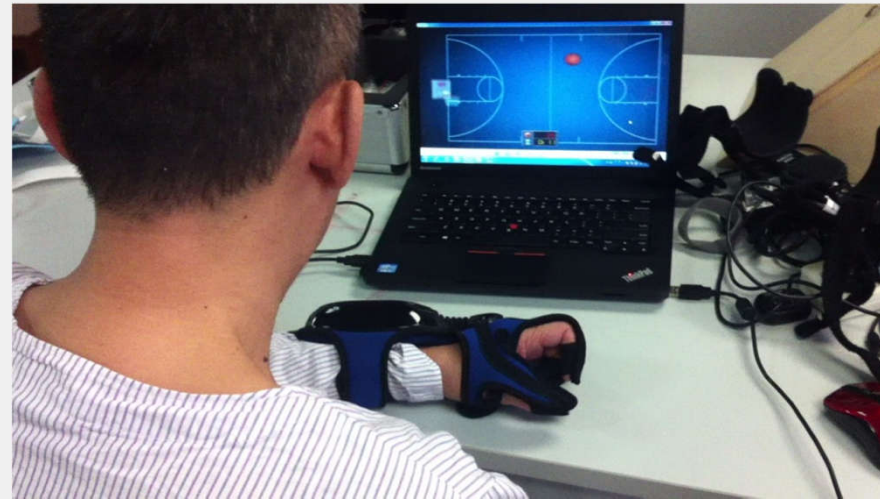


OUTCOME MEASUREMENT & PROCESSING





Mechanism on biofeedback intervention on upper limb for stroke



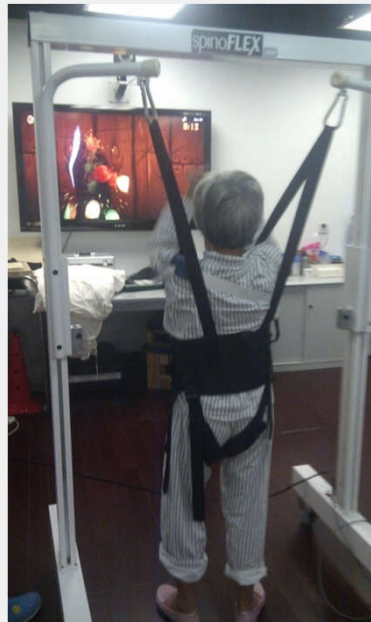


VR training and effects analysis

Training program

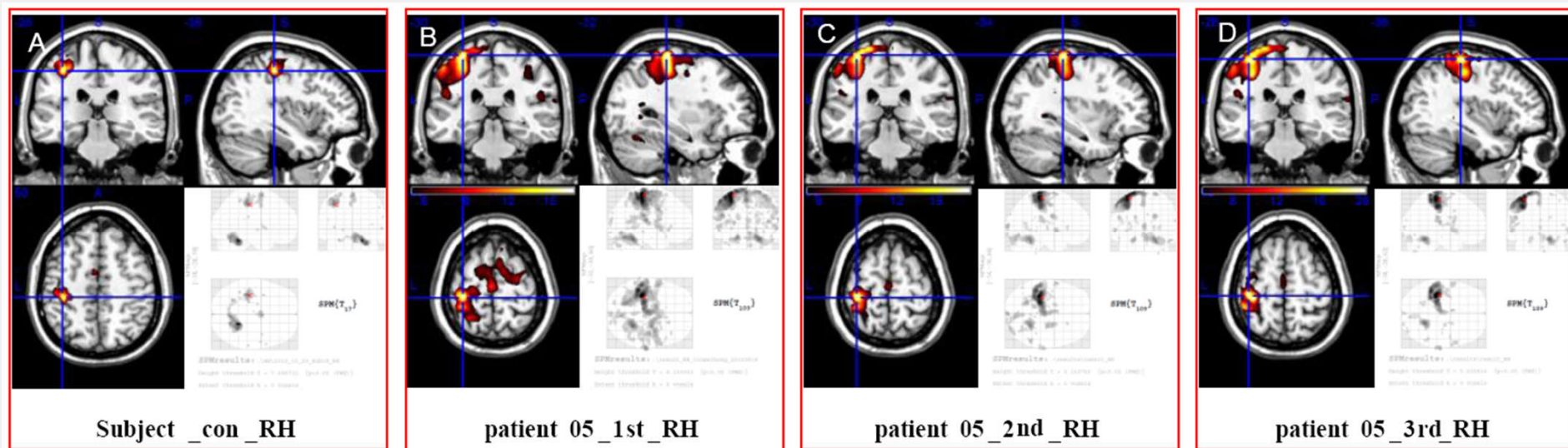
The training lasted for 3 weeks. The training would be done 5 times per week and 30 minutes for each time. Each minigame lasts about three minutes, so they would finish ten sets one session.

We would use the software 《Kinect Adventure! 》 and the 《Fruit Ninja》 to train the VR group.





fMRI study



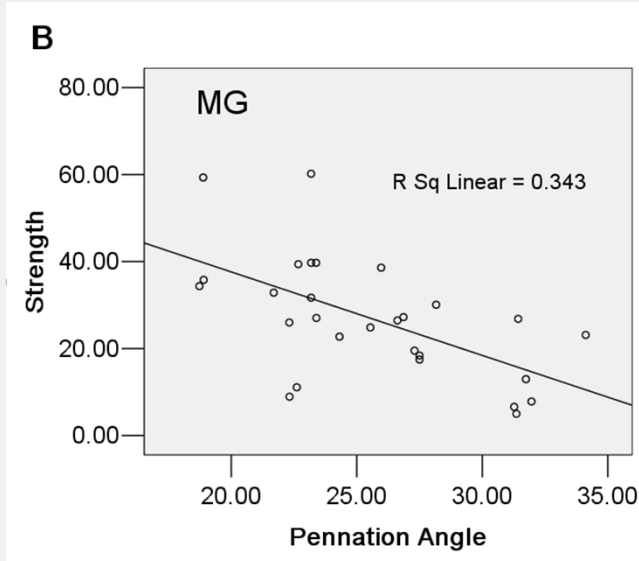
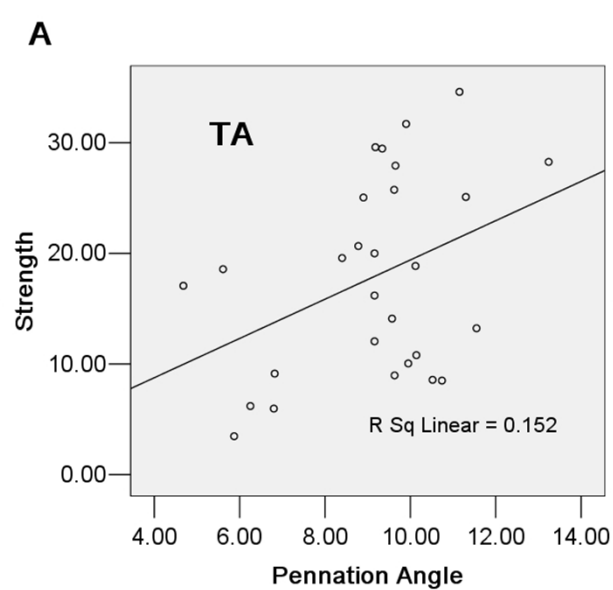
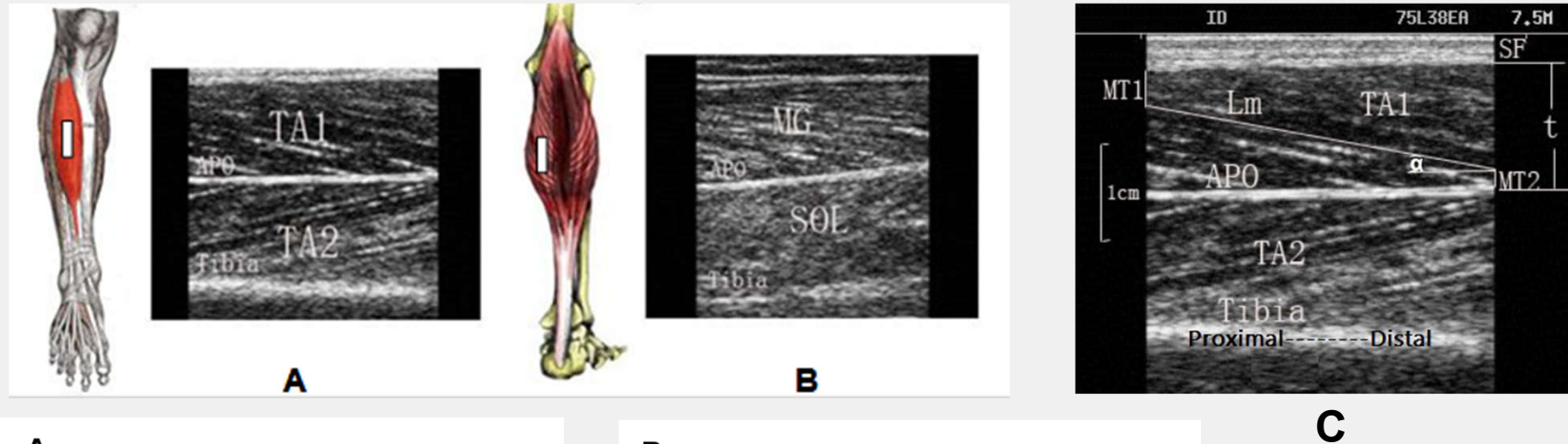
Effect of Kinect-based virtual reality training on regions of interest in primary sensorimotor cortex of five stroke patients. Images are the average brain activation map (A) for patient 5 during fist-clenching with right hand before (B) and 3 weeks after training (C) and 12 weeks follow-up (D). Primary sensorimotor cortex cluster sizes of patient 5 gradually decreased.

Bao et al., 2013 Neural Reg Res





Ultrasound study



Liu et al., 2014 *Biomed Res Int.* 2014;270676. doi: 10.1155/2014/270676





Project ongoing...





寻求新的发展空间

- 世界卫生组织康复合作中心新阶段的工作
- 2012广东省教育厅联合培养研究生示范基地：联合单位为中科院深圳先进技术研究院李光林团队
- 2012广东省人社厅博士后创新实践基地：合作单位为广东省工伤康复医院
- 2013广东省科技厅批复广东省康复医学与临床转化工程技术研究中心
- 2013国家临床重点专科建设项目(广东唯一)
- 2016 广东省康复产业技术创新联盟





前期研究和正在进行的课题

剪切波超声成像用于评估脑卒中 后肌肉弹性研究





大纲

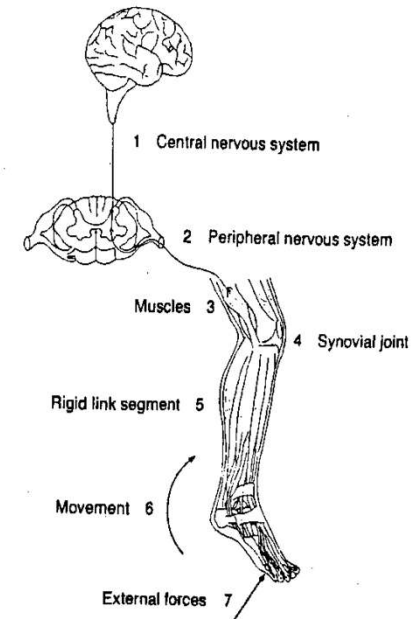
- 研究背景
- 临床问题和现状
- 超声剪切波定义
- 研究方法
- 前期预实验结果
- 讨论





肌挛缩症（Muscle Contracture）

- 肌肉挛缩（**muscle contracture**），因肌肉肌腱长度缩短造成关节功能受限，是肌肉痉挛的后遗症之一；
- 传统观念认为上运动神经元（**Upper Motor Neuron**）损伤所致的肌力下降是由拮抗肌痉挛（**Spasticity**）引起，并进一步发展为肌肉挛缩。



然而近年来也有研究发现神经受损后（例如脑卒中）肌力下降主要由神经因素和失用导致的肌肉适应性改变引起。





脑卒中后的挛缩肌肉肌腱情况

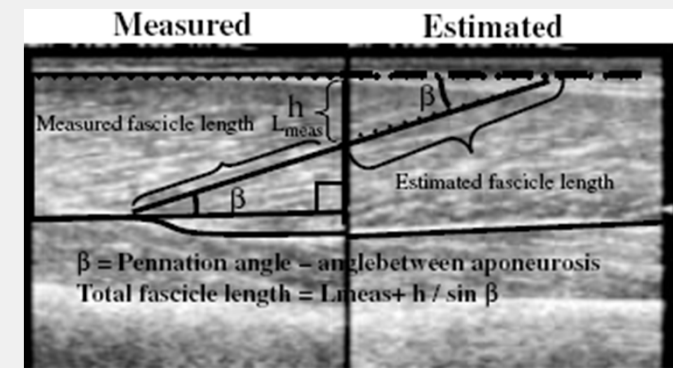
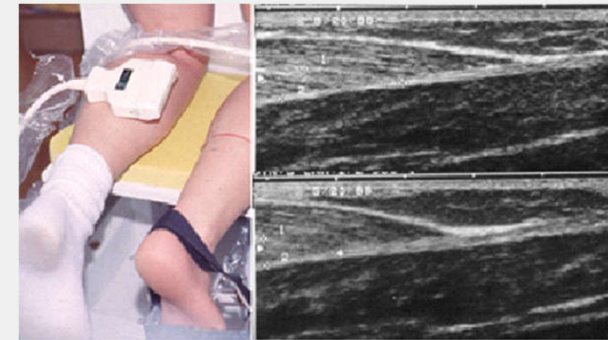
- 脑卒中（**stroke**）发病率、致残率双高(Delisa, 2004; Winter, 2005)。随着我国**人口老龄化**的不断增长，脑卒中的发病率也随之上升。

- 肌肉挛缩是脑卒中常见后遗症。

- 卒中后肌肉肌腱的变化（形态学证据）：
肌肉体积（muscle volume）变小（Metoki et al., 2003);

肌纤维（fascicle length）缩短(Becher et al., 1998; Gao et al., 2009);

肌肉肌腱参数和肌肉发力和关节运动直接相关
(Lieber and Friden, 2000; Fukunaga et al., 1997)。





临床问题和研究现状

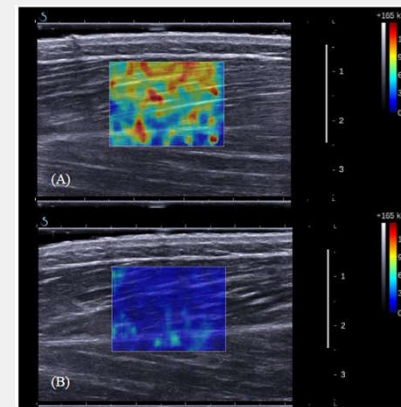
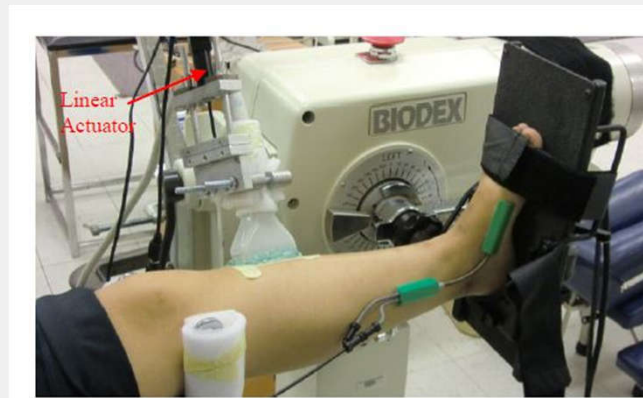
- 当前对挛缩的关注还**主要在于治疗方面**，比如应用被动牵拉和肉毒毒素注射，观察其疗效，或者研究各种运动疗法和肌力训练方案对挛缩的缓解作用。
- 临床评估挛缩主要**局限于徒手和简单的量表**，但是这些方法是直接根据医生的观察和简单测量对患者的关节运动做出描述。





剪切波超声弹性成像 **Supersonic shear wave elastography (SSWE)**

- SWE可测量反映组织弹性的杨氏模量(Young's modulus) 的绝对值。系统通过探头发射声辐射脉冲对组织施加激励，在组织中产生足够强度的剪切波;
- 通过系统的定量分析系统测量组织的杨氏模量值(kPa)



Koo et al., 2014





SWE人体组织成像应用

- 腺体：乳腺，甲状腺等
- 器官/脏器：肝脏，脾脏等
- 骨骼肌





临床问题和研究现状（续）

- 近年来**超声剪切波技术**的出现, 可无创评估肌肉内部微观结构的弹性。
- 有研究表明**肌肉长度及弹性的变化与肌力相关**, 特别是肌肉因伸缩形变引起的被动肌力与肌肉形态关系明确。
- 但**挛缩状态肌肉弹性**与肌力相关性的超声剪切波研究还较少





研究问题

- 剪切波弹性成像是否可以应用于脑卒中后肌肉张力以及挛缩情况评估？
- SWE参数与临床常规量表有什么相关性？



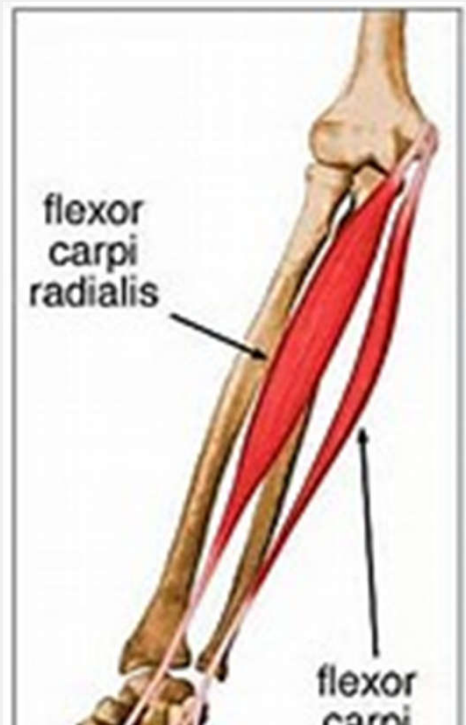


研究目标

- 1.研究脑卒中后偏瘫侧腕屈肌的肌肉弹性剪切波模量值与改良**Ashworth**肌张力分级、**Neuroflexor** 测量肌肉张力及弹性之间的关系
- 2.探讨剪切波弹性成像技术应用于临床无创检查量化肌肉痉挛程度的可行性。



设备和肌肉的选取（腕屈肌）



Supersonic Aixplorer



中山一院超声科



合作伙伴-瑞典皇家工学院



Moving spasticity measurement forward

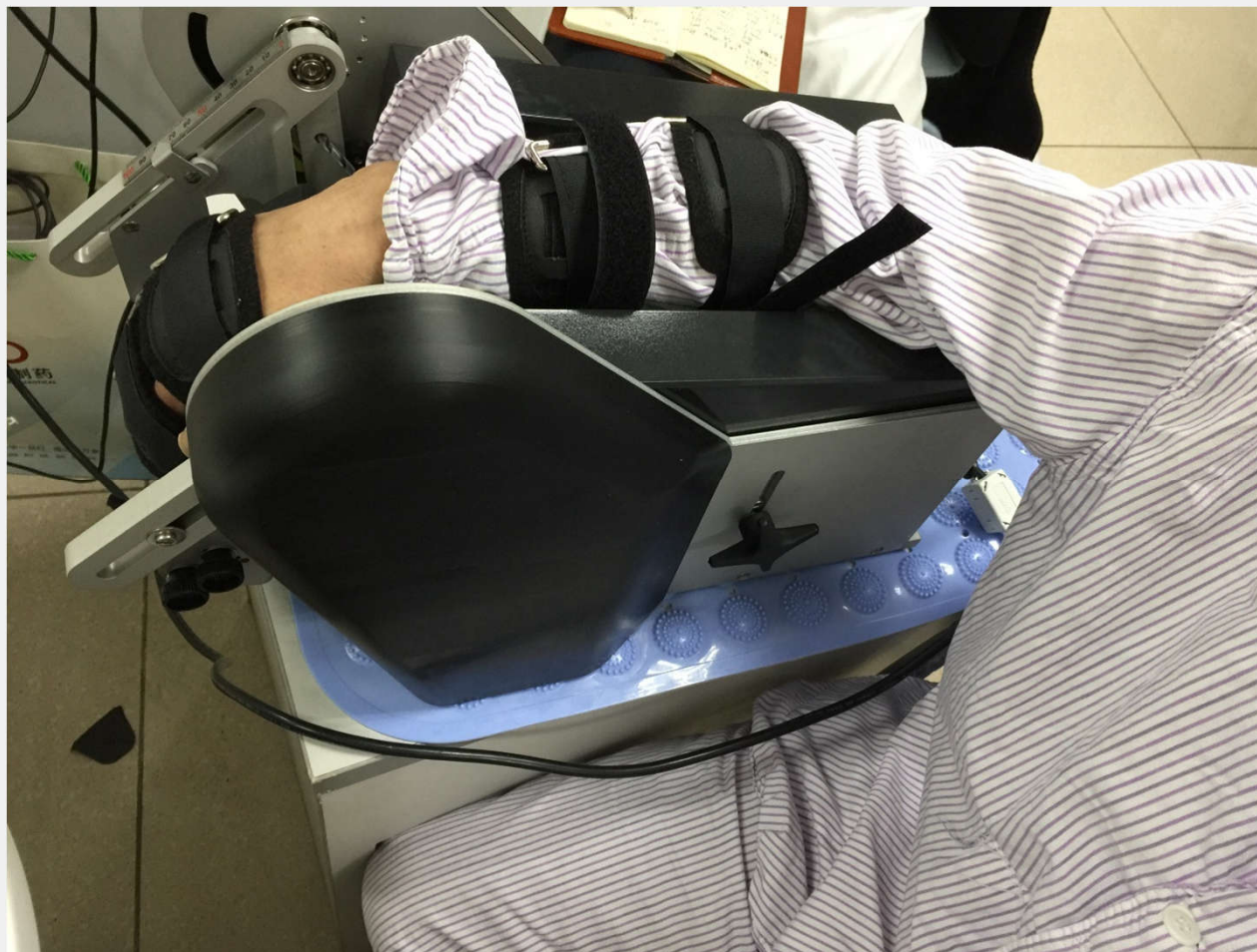
提出一个新的方法可以估算脑卒中偏瘫患者的腕关节屈伸肌的肌痉挛自有性质，例如：运动神经元，肌梭以及肌肉组织性质的变化；研究肌痉挛相关的神经和非神经相关性质与上肢伸手抓物的表现的相关性。

患者将腕部放置于NeuroFlexor设备中，在机器带动下进行被动屈伸。系统根据加速度变化和力矩结果，应用生物力学建模方法推算出肌肉痉挛参数。





设备（续）



NeuroFlexor

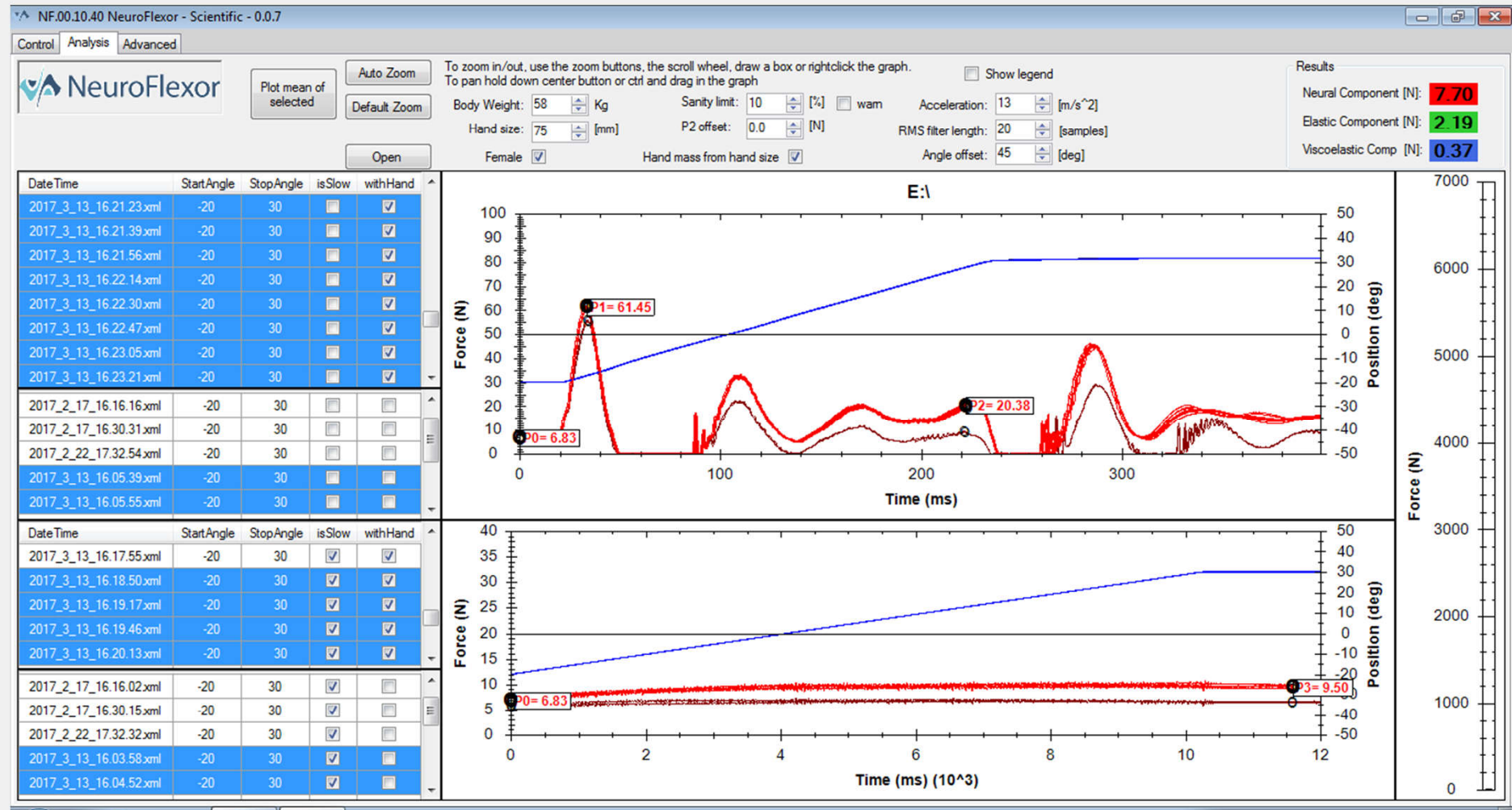




NeuroFlexor---Spasticity

- 提出一个新的方法可以估算脑卒中偏瘫患者的腕关节屈伸肌的肌痉挛自有性质，例如：运动神经元，肌梭以及肌肉组织性质的变化；研究肌痉挛相关的神经和非神经相关性质与上肢伸手抓物的表现的相关性。
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NeuroFlexor testing on one of our stroke survivors with MAS = 1+





方法：选择脑卒中后上运动神经元损伤所致腕屈肌肌张力升高患者，MAS分级 ≥ 1 级，通过弹性剪切波成像技术测量腕屈肌 $0^{\circ} \sim 50^{\circ}$ 被动牵伸时的模量值，与MAS分级及Neuroflexor测量的肌肉弹性、粘性值进行相关性分析。

姓名：梁** 性别：男 年龄：37岁

影像号：00693913

检查部位：其他临床诊断：继发性癫痫 高血压病3级 极高危组 左侧基底节区脑出血恢复期

超声描述：

111

超声提示：





B

Pen/FR/H
M 6/67 dB/Low
T 1540 m/s
SC/SR 2
G 37 %
Fr. 12 Hz

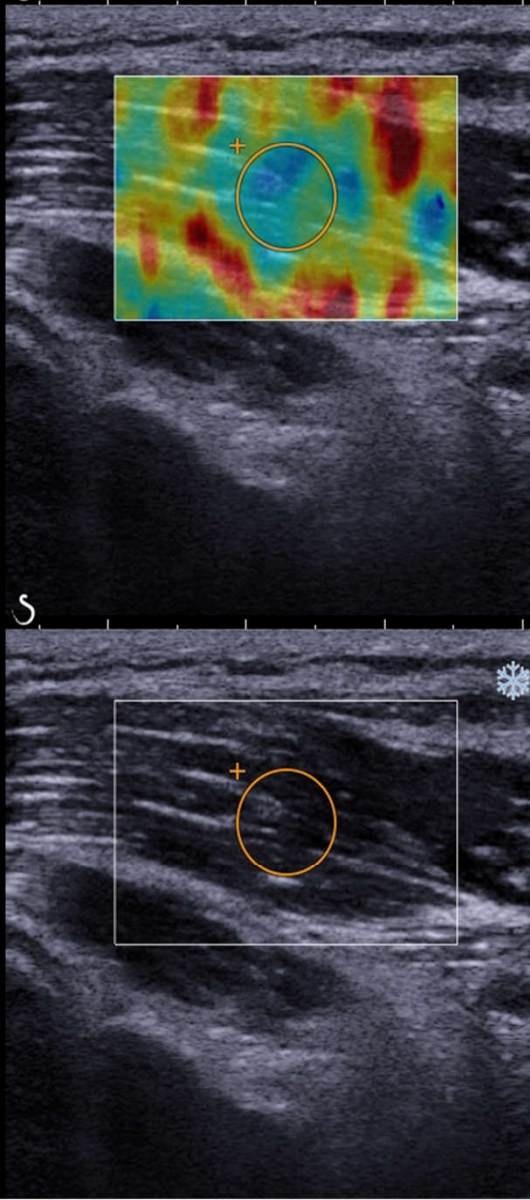
SWE™

Pen
M 1/High
S 5/O 50 %
G 70 %

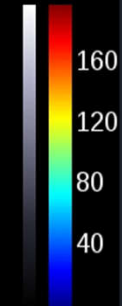
Z 110 %

S

S



≥200 kPa



0.0

- 1.0

- 2.0

+Q-Box™

- Mean 77.9 kPa

- Min 56.1 kPa

- Max 106.6 kPa

- SD 12.8 kPa

- Mean 5.1 m/s

- Min 4.3 m/s

- Max 6.0 m/s

- SD 0.4 m/s

- Depth 1.3 cm

- Diam 7.00 mm

- 2.0

- 3.0



姓名：鲁* 性别：女 年龄：54岁

影像号：00693912

检查部位：其他临床诊断：大动脉粥样硬化性脑梗死（右侧基底节区-放射冠-半卵圆、右枕叶） 右侧大脑中动脉M1段、基底动脉局部重度狭窄、闭塞 高血压病3级 很高危组

超声描述：

11

超声提示：





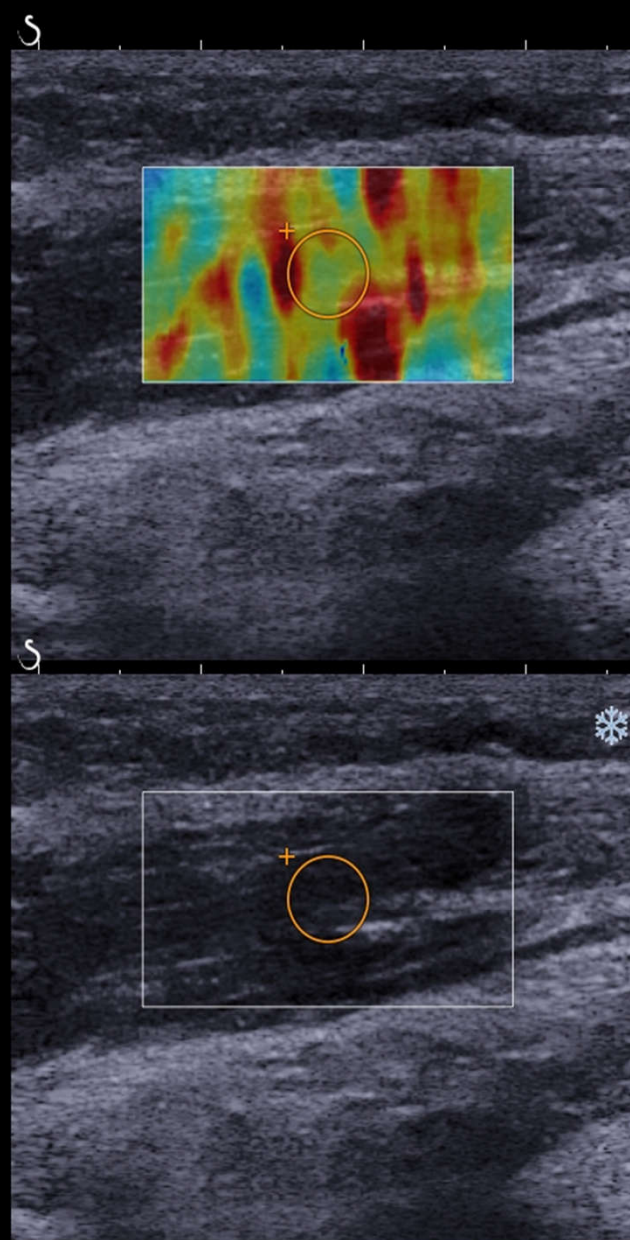
B

Pen/FR/H
M 6/67 dB/Low
T 1540 m/s
SC/SR 2
G 47 %
Fr. 12 Hz

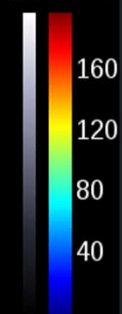
SWE™

Pen
M 1/High
S 5/O 50 %
G 70 %

Z 115 %



≥200 kPa



0.0

- 1.0

- 2.0

+Q-Box™

Mean 131.1 kPa

Min 107.8 kPa

Max 226.2 kPa

SD 23.0 kPa

Mean 6.6 m/s

Min 6.0 m/s

Max 8.7 m/s

SD 0.5 m/s

Depth 1.3 cm

Diam 5.00 mm

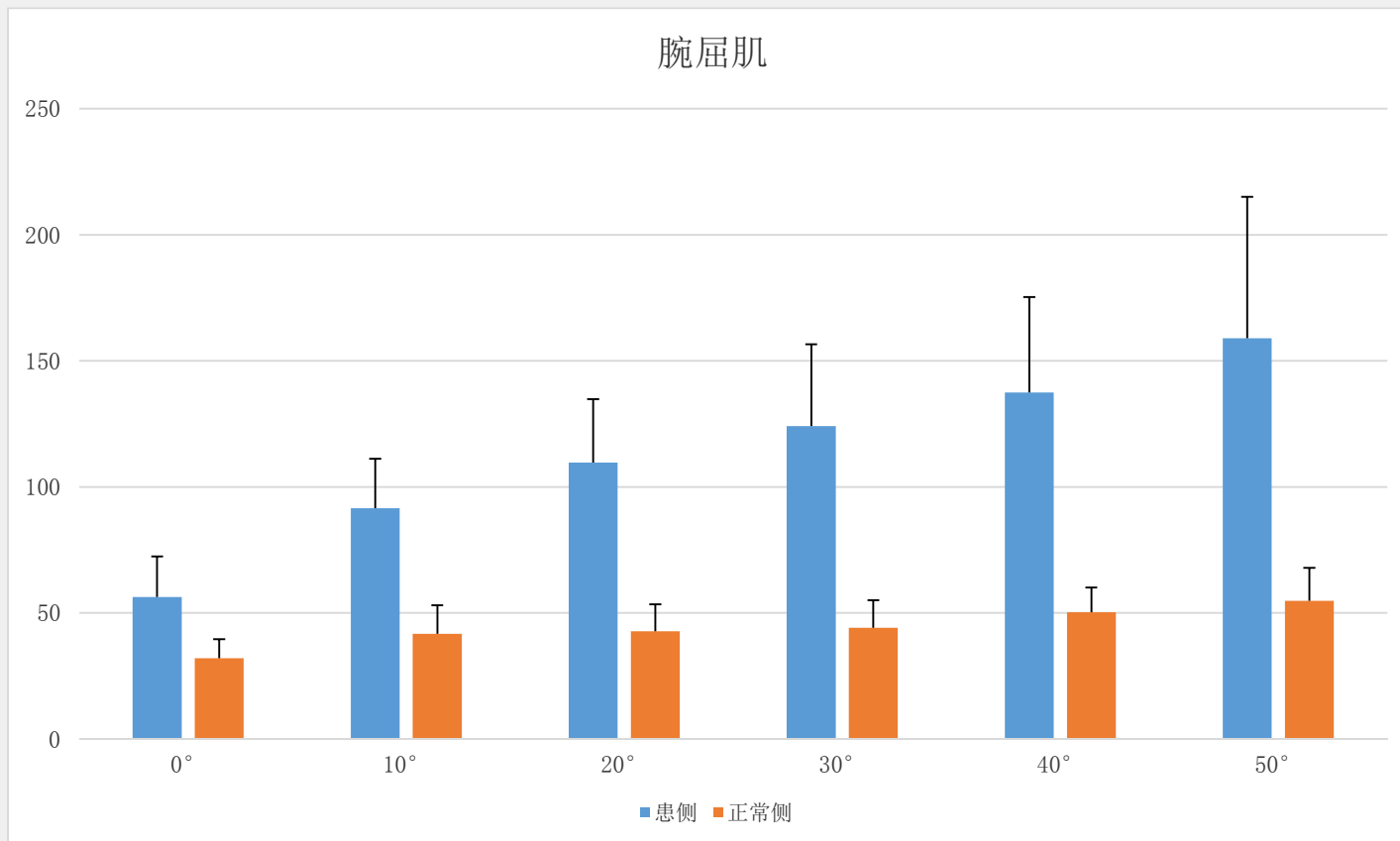
Display Saturated

- 2.0

- 3.0



结果



结果：7例患者中患侧腕屈肌的弹性模量值比正常侧升高，随着腕屈肌被动牵伸的角度越大，患侧弹性模量值升高的幅度比正常侧更高。





讨论

- **SSE**超声剪切波可以用于痉挛状态下的肌肉参数评估
- 超声测量到的弹性模量值可以与**Neuroflexor**的参数进行相关性分析



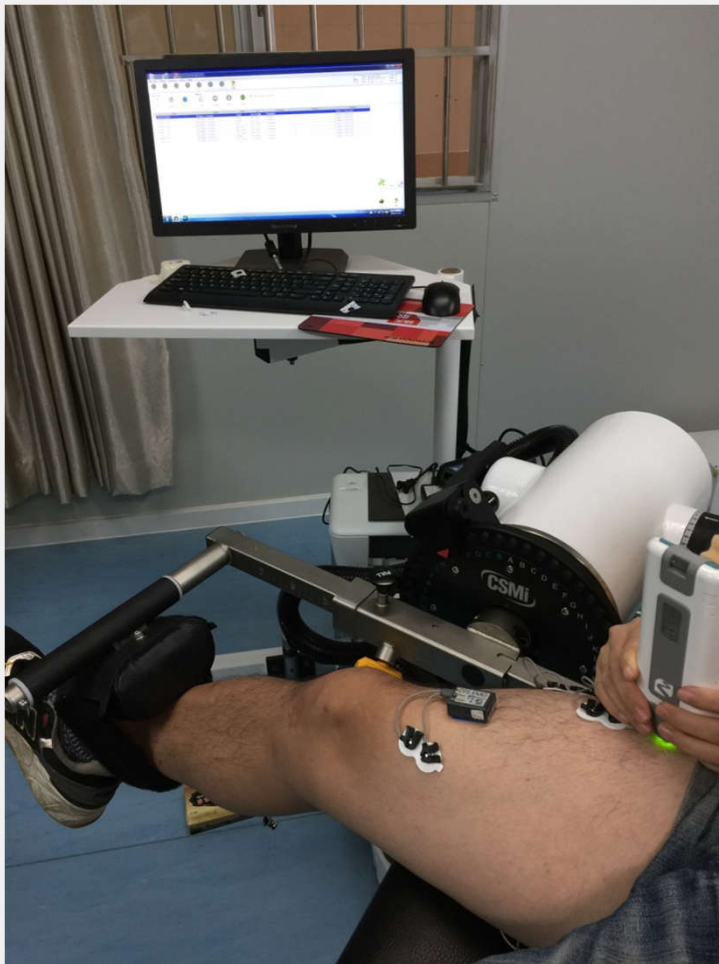
Future study

- 利用超声获得正常人和脑卒中关节主要发力肌肉肌腱的**形态结构参数**, 结合**肌电信号**, 建立机电驱动的**正向肌骨模型**;
- 引入**超声剪切波成像技术**, 在不同关节角度对预测的主动和被动单一肌肉发力做验证;
- 结合等速, 获取关节的力矩, 探讨肌肉挛缩状态对运动功能的影响, 揭示正常与病理条件下**肌肉肌腱的力学特性**的改变与运动模式的**内在联系**。





多关节等速



Myoton meter



- 测量完全无创无痛快速，能提供量化的反映肌肉功能状况的参数（肌肉张力、肌肉弹性、肌肉硬度、德博拉数、肌肉内部压力释放时间），可应用于指导运动员的训练和恢复，对肌肉疲劳损伤的监测和预防，或者对肌肉病患者的康复提供有用的信息，可对康复疗效进程进行评估，能协助医生及时调整优化治疗方案





宽景成像研究





宽景成像-合作伙伴-华工

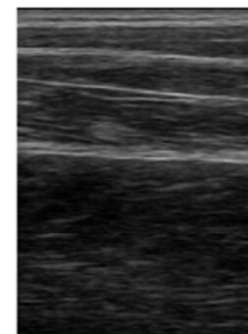
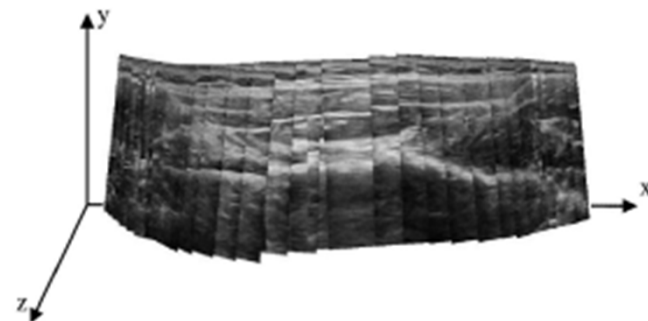


图1-2 手臂肌腱普通B超图

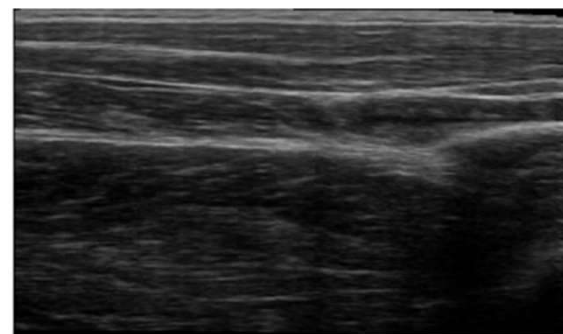


图1-3 手臂肌腱B超宽景成像图



医学超声2.5维宽景成像研究背景

医学超声2.5维宽景成像是指借用三维超声成像的原理，利用三维位置传感器对超声探头进行实时定位，在获取二维超声图像的同时能获取每幅图像准确的位置信息，以此实现能够复原真实探头移动轨迹的曲面宽景成像。

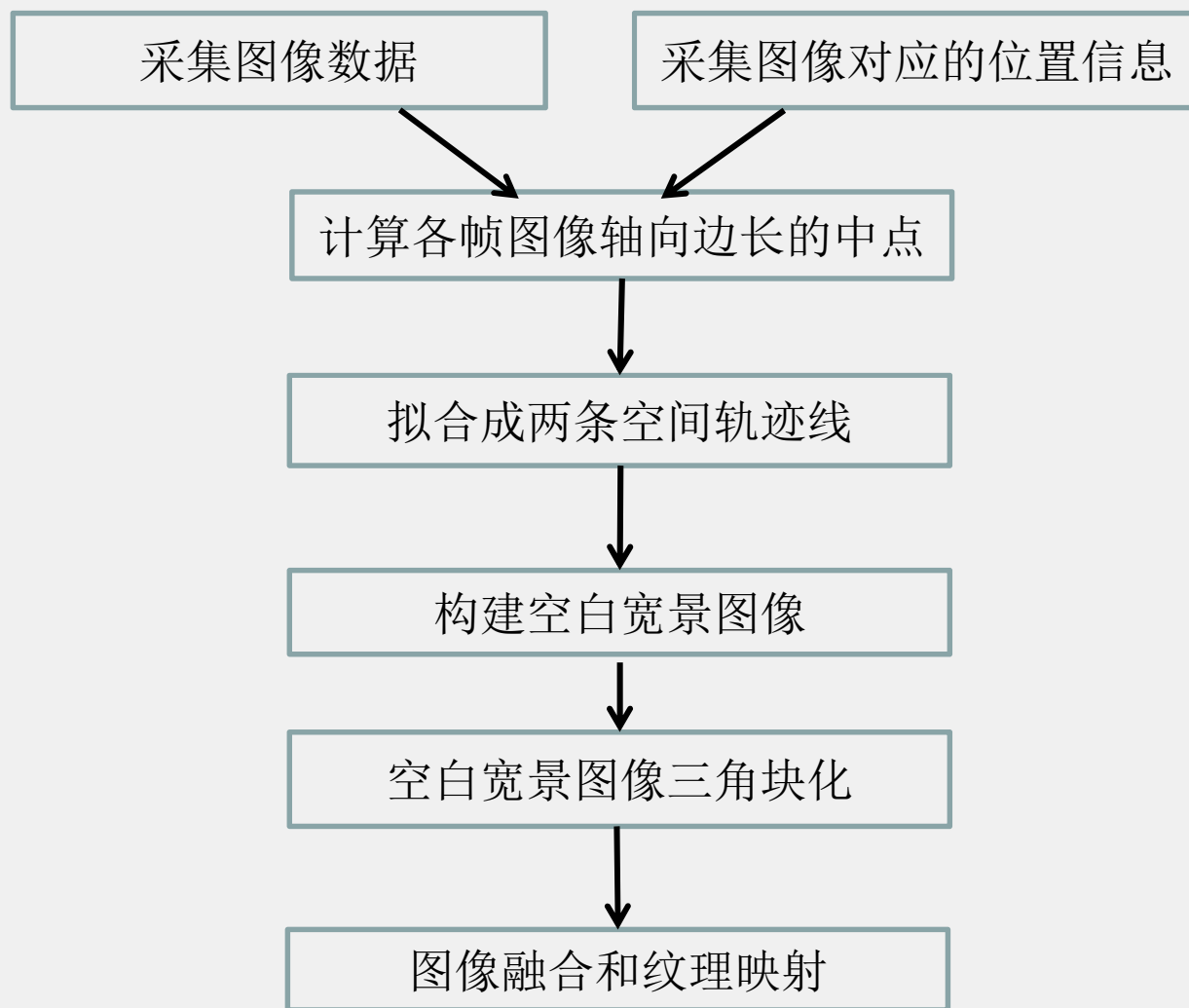
在医学超声成像领域，能获取宽景图像的技术包括：二维宽景成像技术、三维成像技术和三维宽景成像技术。然而这些成像技术存在着诸多不足：传统的二维宽景成像技术配准耗时、对结果干扰较大，在图像的扫描过程中对探头移动限制多；三维成像技术高昂的价格限制了三维超声探头的推广使用，并且大量的数据计算导致三维成像速度较慢，人机交互体验不理想；三维宽景成像技术是于近年来刚提出的一种宽景成像技术，其技术不成熟，有待进一步研究与发展。





该技术对二维、三维宽景成像进行了改进：①在空间维度上进行了拓展，将宽景图像呈现在三维空间中，这样便能准确的表达图像的实际空间关系，而不用将每一帧图像都拼接到同一个平面中；②改变图像配准方式，不再依靠图像特征，而是利用图像的空间位置信息来合成图像，提高了成像速度。同时相对于三维超声成像技术与三维宽景成像技术也有了很大的改进：无需重建出感兴趣区域的宽视野三维图像后，再对三维图像进行切片以获取宽景图像。2.5维宽景成像技术在数据采集过程中，探头仅需沿着感兴趣区域扫描采集切面图像序列即可。通过一定方法便可将该图像序列直接合成扫描区域的宽景图像。同时，无需进行三维图像的重建避免了庞大的体数据处理；只需要对三维形体的表面进行绘制，保持了图像原有的分辨率。





基于贝塞尔曲线的2.5维宽景成像系统框图





安装有3D Guidance
trakSTAR电子单元



电磁发射器

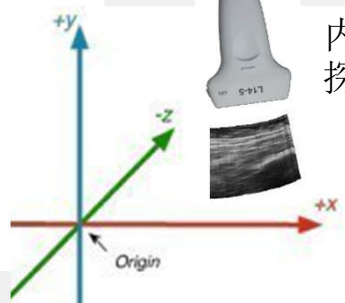
显示器

主机（内置图像采集
卡）

内置位置传感器的
探头

sonixSP彩超

系统结构示意图





内置位置传感器

探头

数据采集过程探头运动示意图



B超图像沿探头横向
方向上边的中点

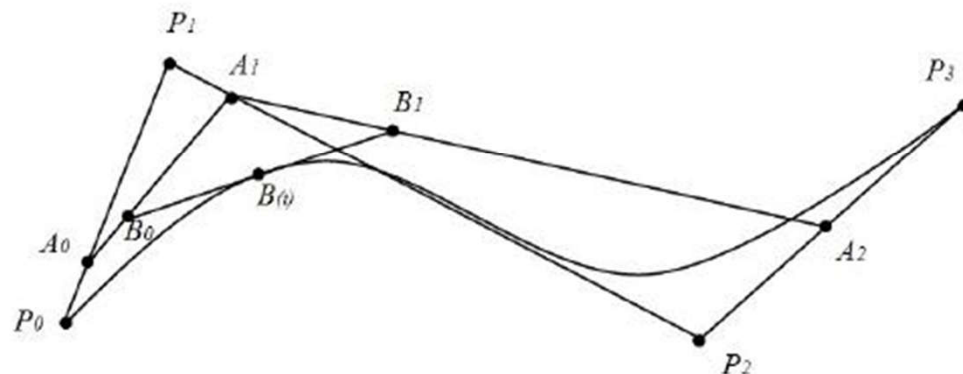
B超图像沿探头横向
方向下边的中点

拟合时选取点所在位置

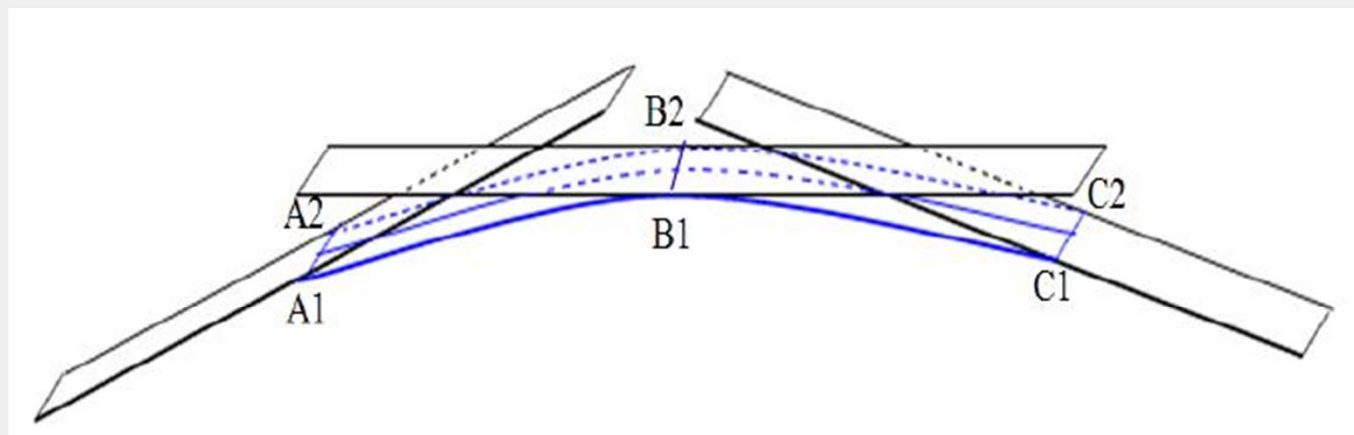




$$B(t) = (1-t)^3 P_0 + 3t(1-t)^2 P_1 + 3t^2(1-t) P_2 + t^3 P_3, \quad t \in [0,1]$$

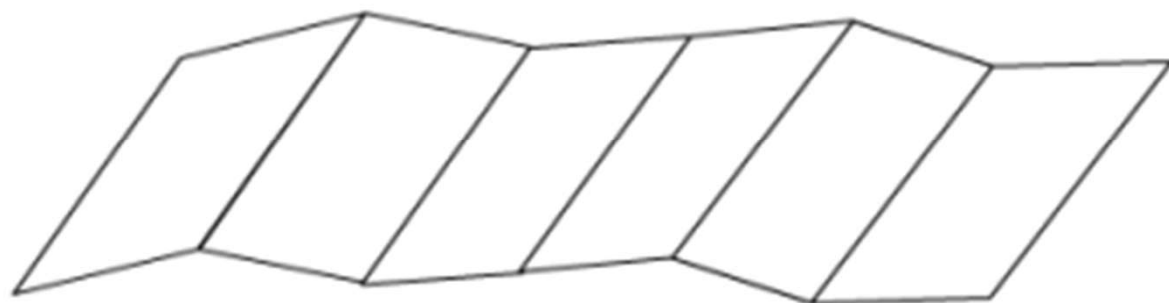


三次贝塞尔曲线的结构



预先构建空白宽景图像的方法示意图



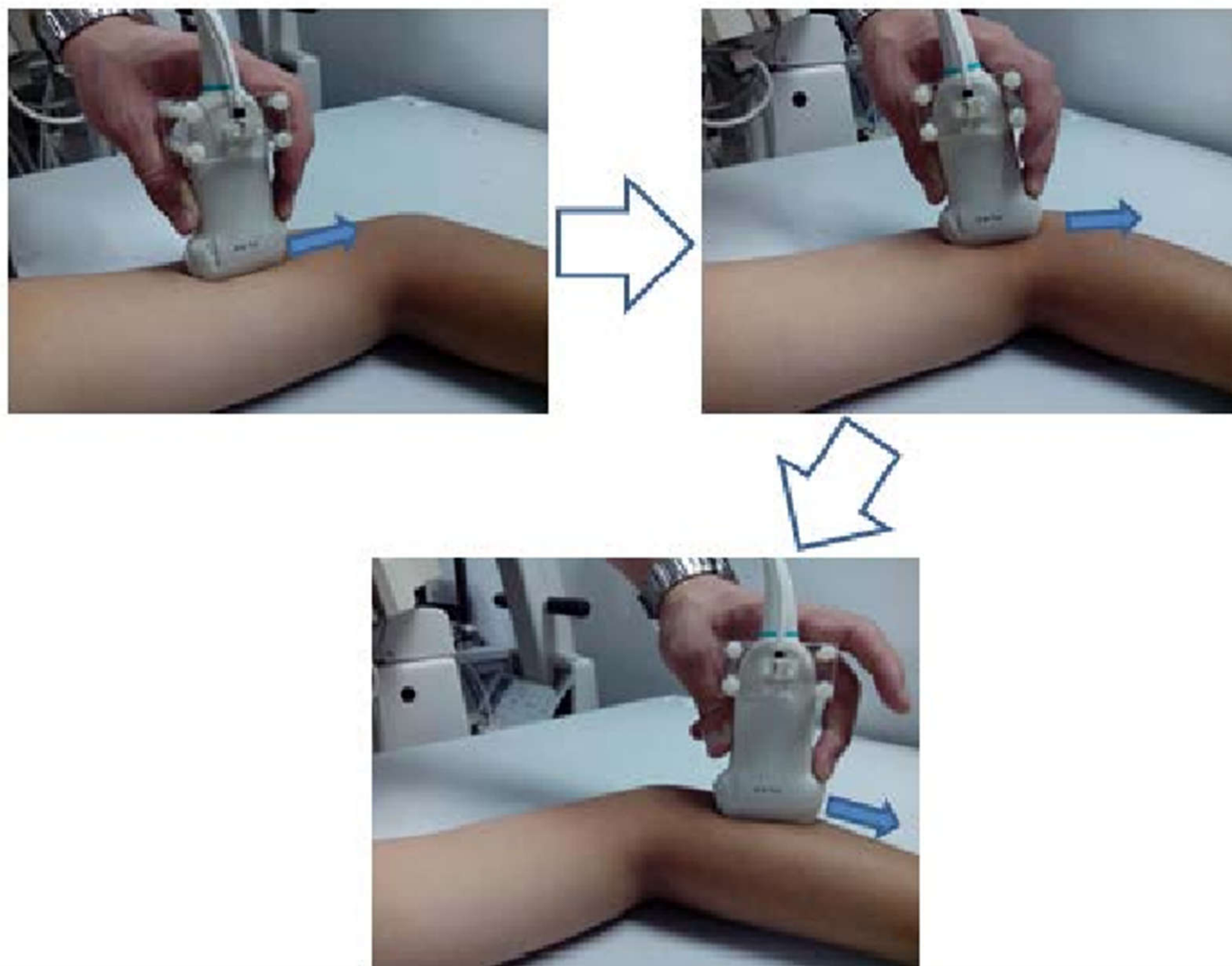


a) 原始空间点



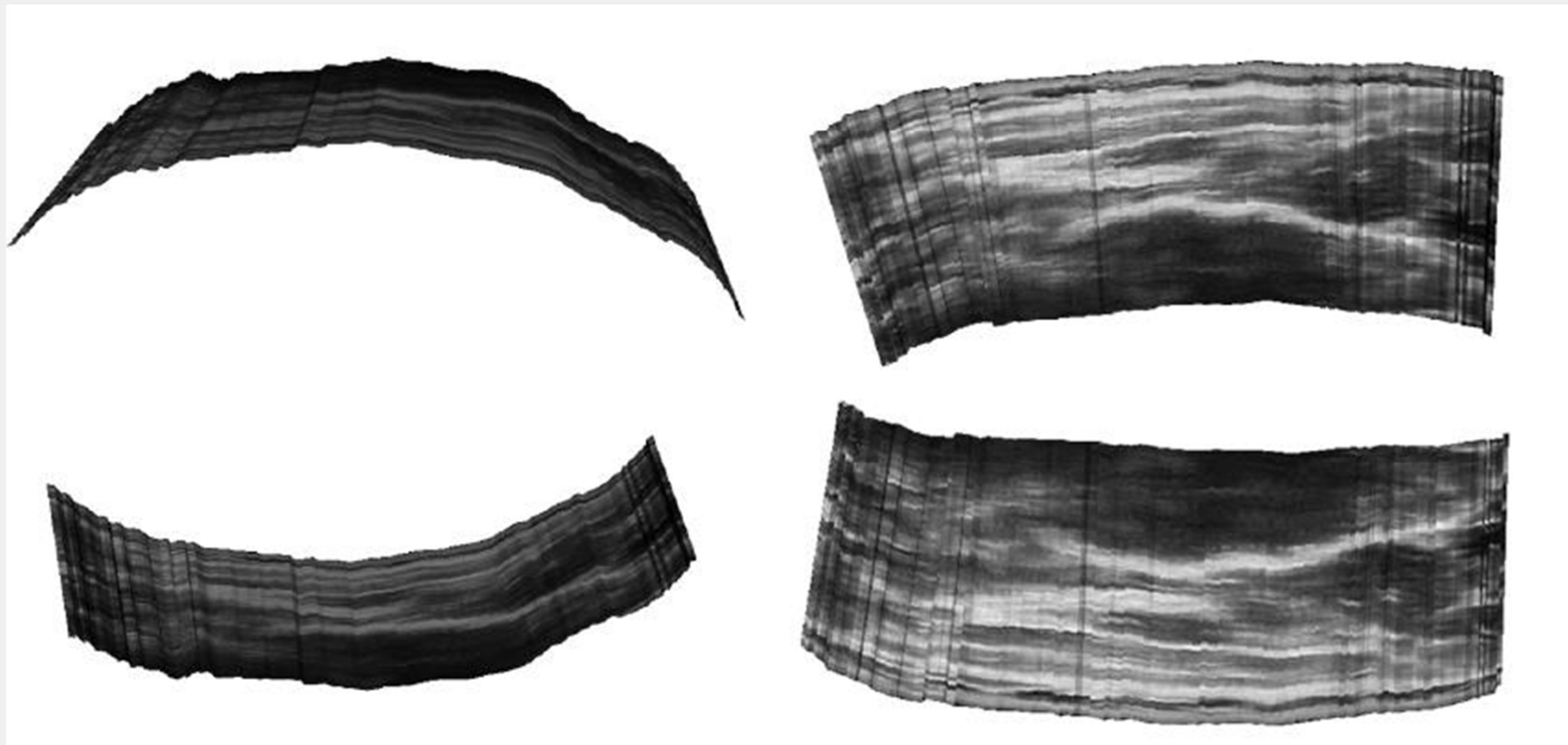
b) 拟合并划分
后的宽景图像





弯曲手臂扫描示意图





弯曲手臂定性实验成像结果

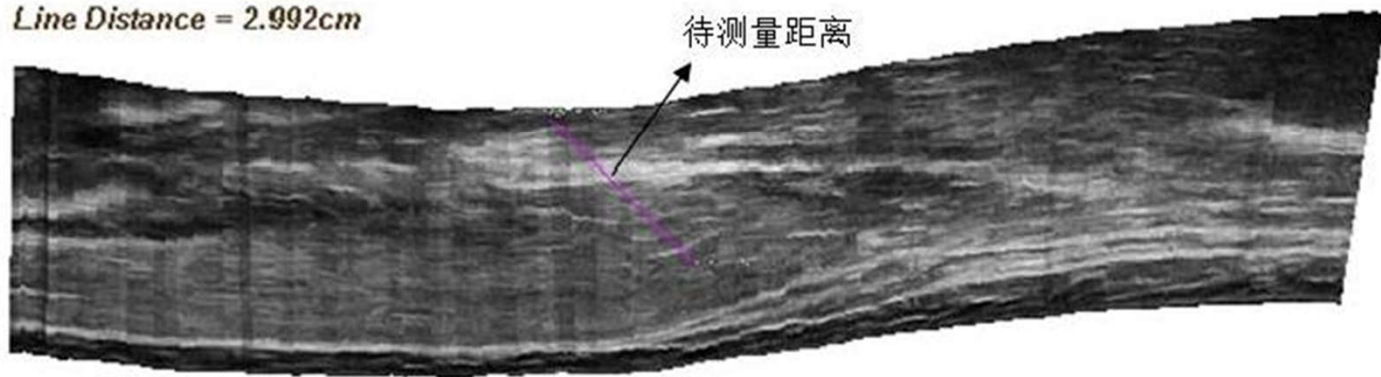




测量结果

Line Distance = 2.992cm

待测量距离



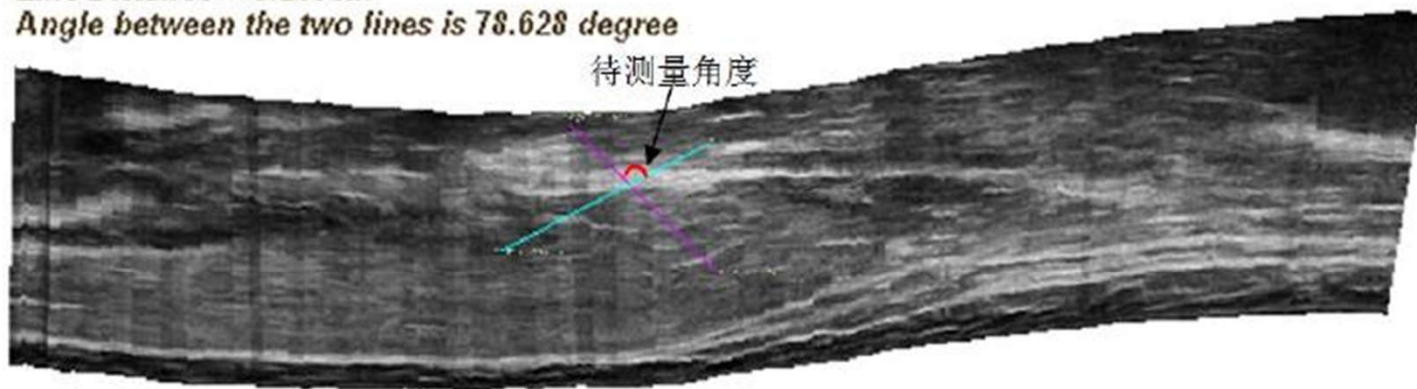
图(a) 测距

测量结果

Line Distance = 3.210cm

Angle between the two lines is 78.628 degree

待测量角度



图(b) 测角度





谢谢！

Q & A



中山大學
SUN YAT-SEN UNIVERSITY

康复机器人技术和电生理评估技术 --美国见行

李乐 副研究员

中山大学附属第一医院康复医学科

2017年5月



The University of Texas
Health Science Center at Houston

McGovern
Medical School

2014.9-2016.9 国家公派美国访学两年





美国访学单位介绍

- 德州大学休斯敦健康科学中心物理医学与康复系
- TIRR赫尔曼纪念医院研究中心

(全美康复排名第二- US News)



With Chair Professor **Dr. Gerard E. Francisco**



With PI Prof. *Ping Zhou* and team members





美国TIRR Memorial Hermann Hospital, main building and Research Center





步态分析





减重步态 (BWSTT)



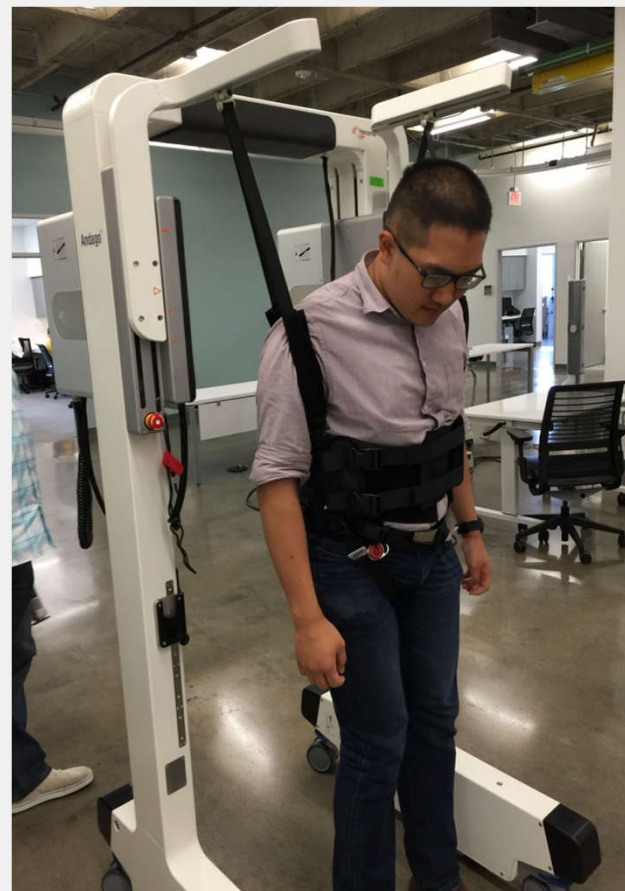
等速多关节 Dynamometer





天轨移动





減重步行架

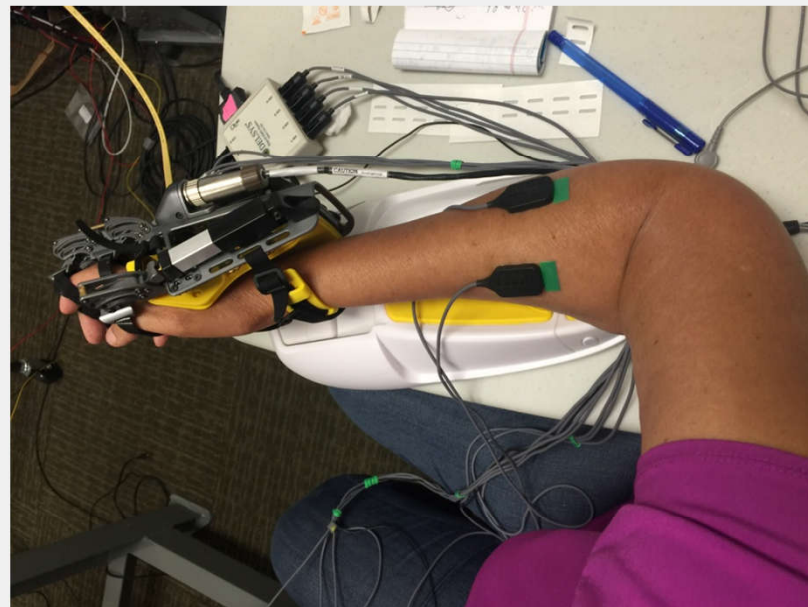


康复机器人介绍 手机机器人



EMG-control of
Hand of Hope Robot





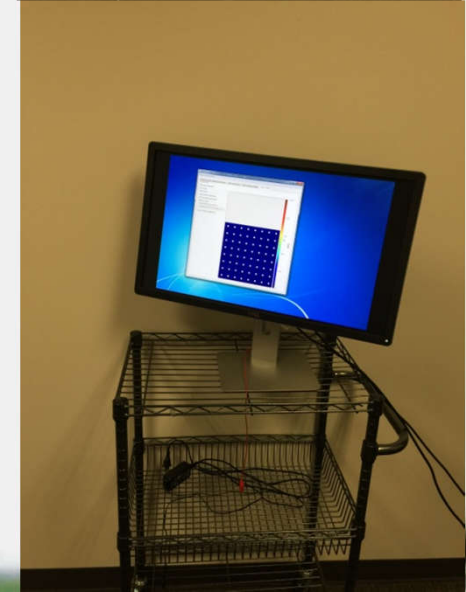
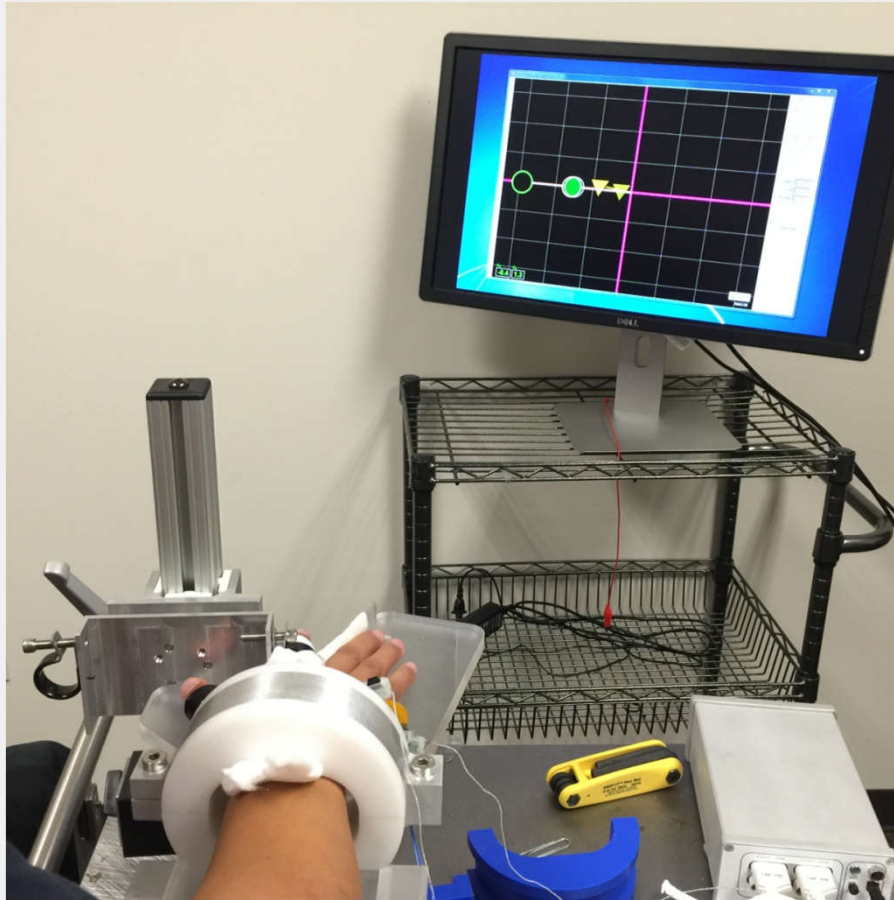
训练示意图

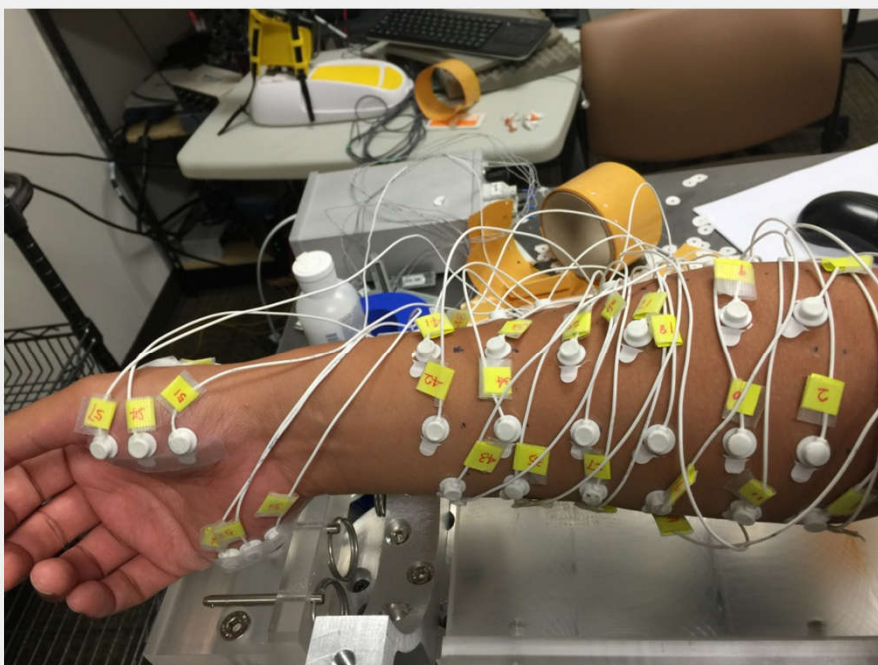
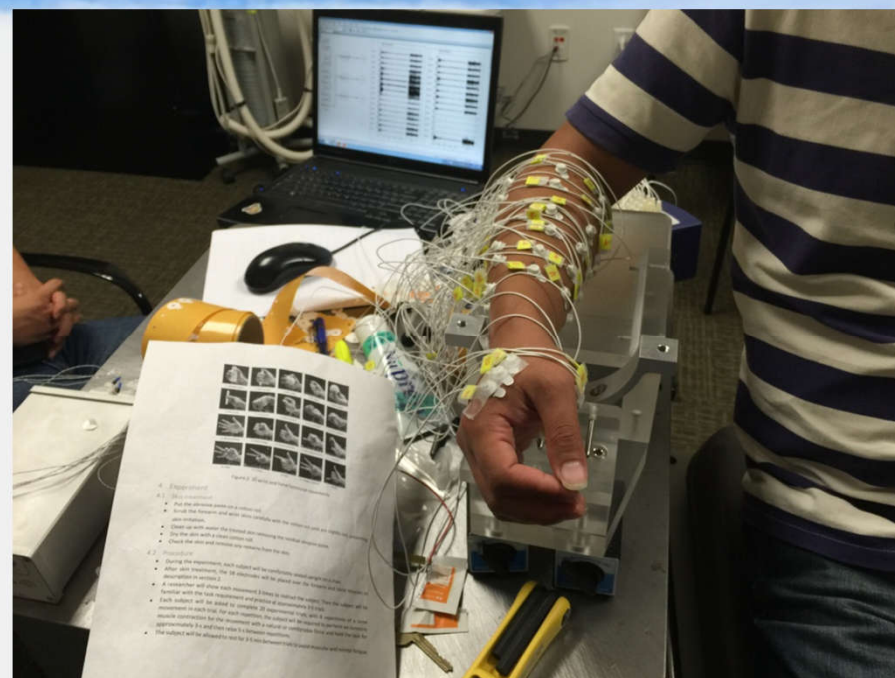
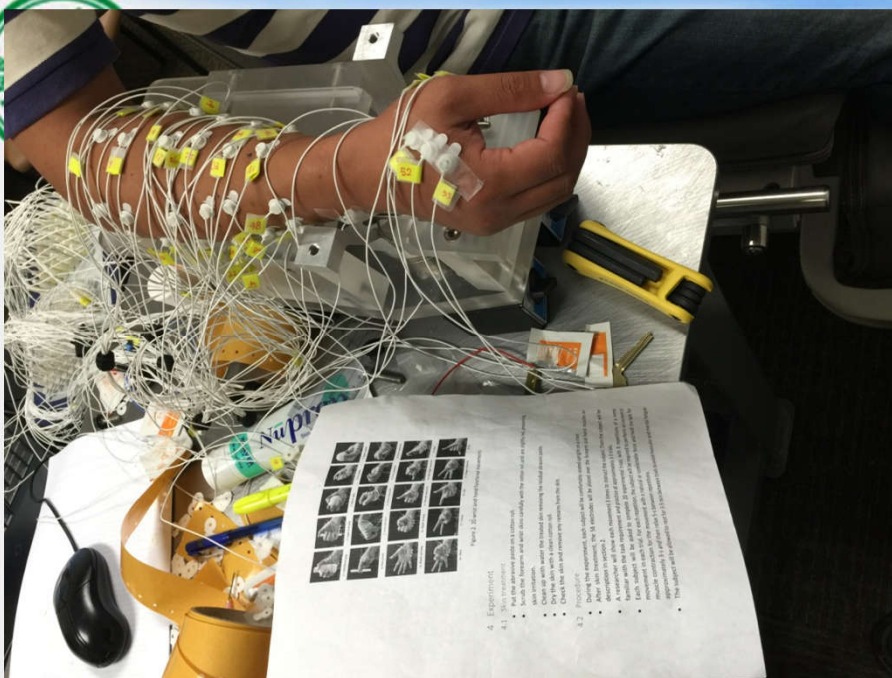




高密度阵列表面肌电

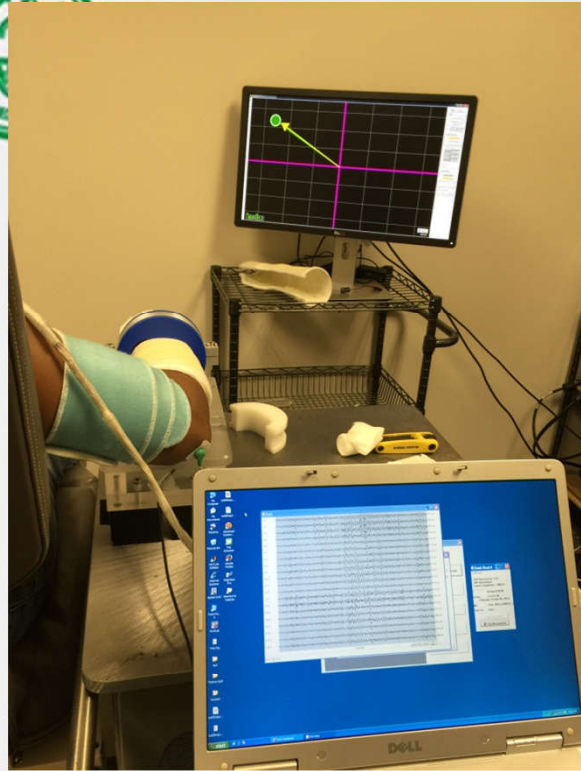
- High Density Surface EMG





Pattern Recognition 高密度阵列表面肌电

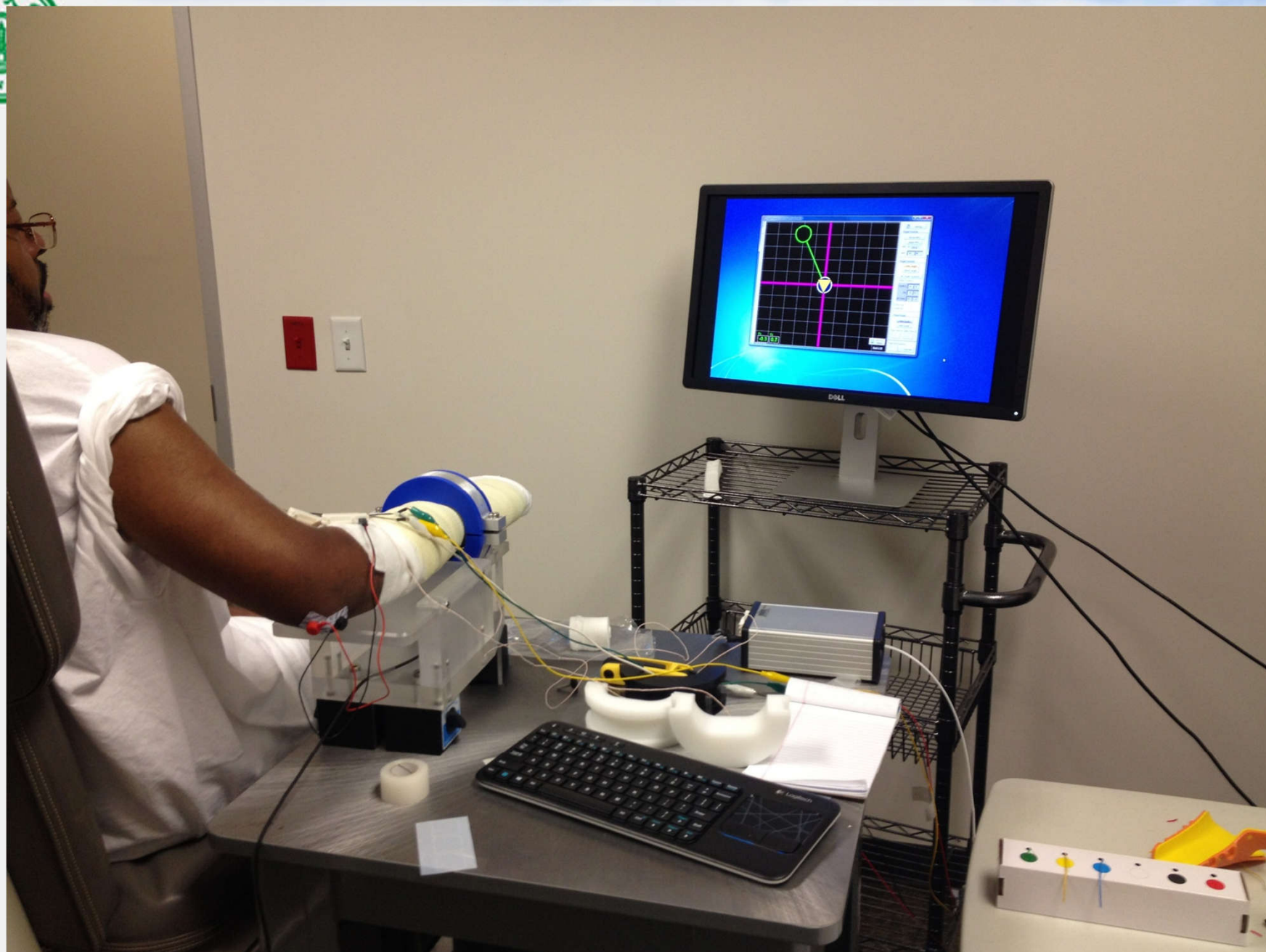




Linear Electrode Array

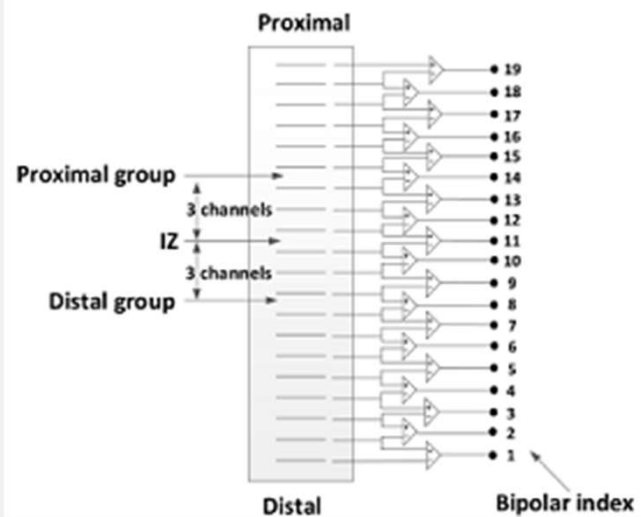
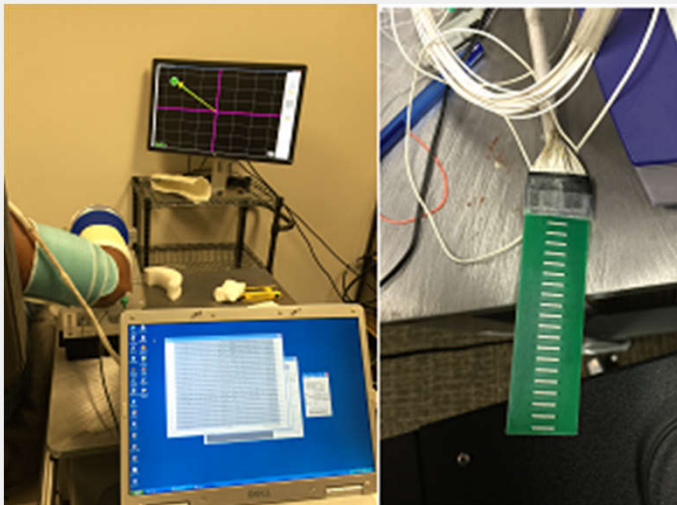
高密度阵列表面肌电



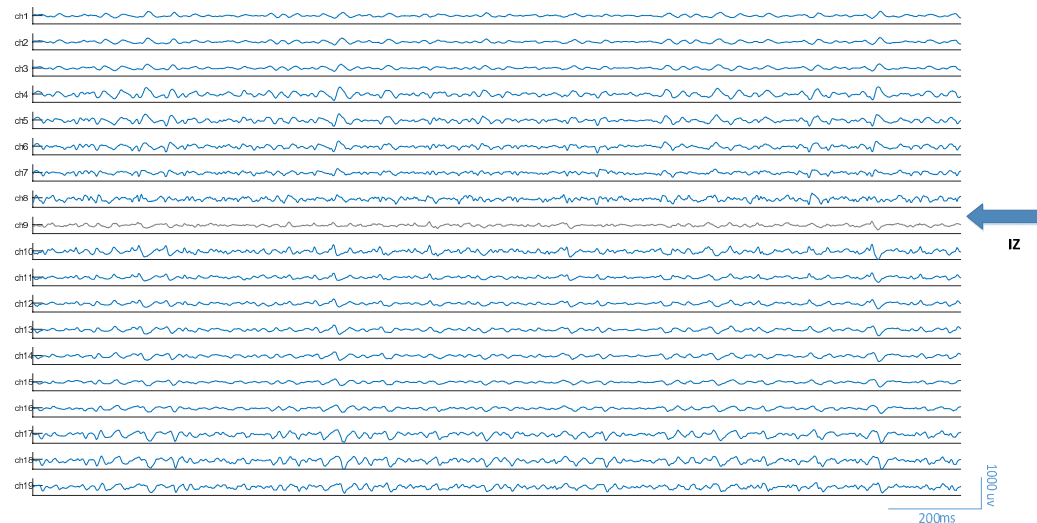




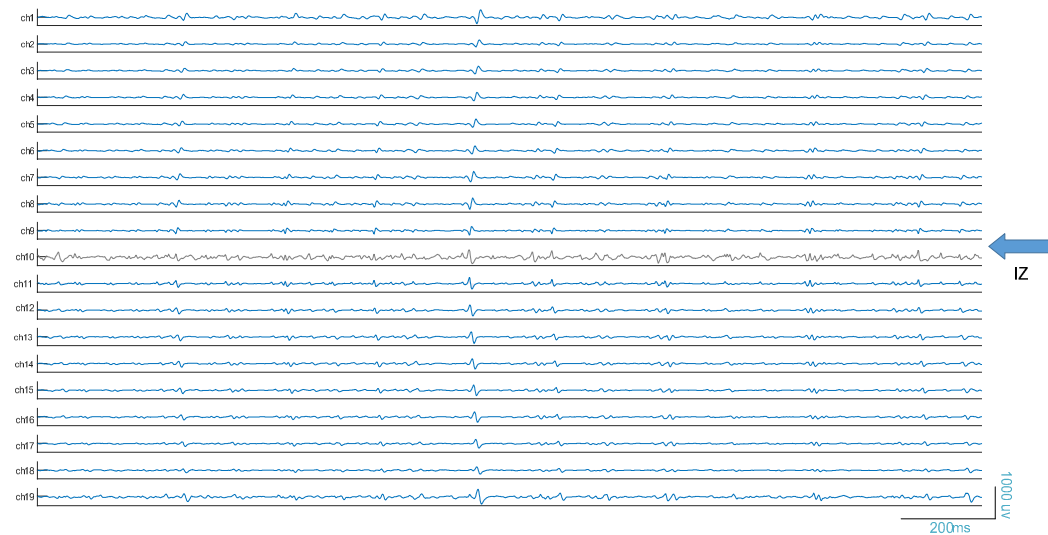
肌肉兴奋性和神经支配区-高密度阵列电极分析



One Control Subject



One SCI Subject

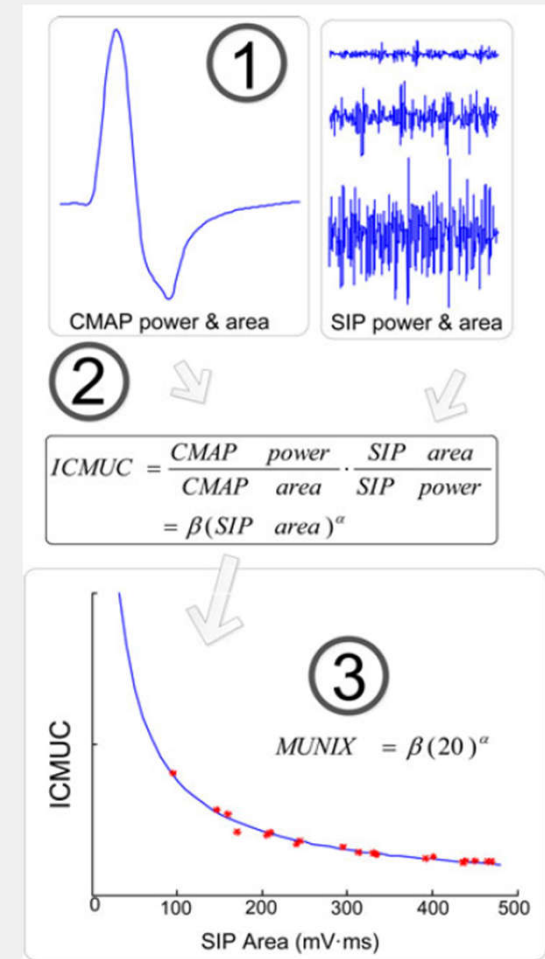




运动单位数目指数 (MUNIX, Motor Unit Number Index)

MUNIX是近来出现的一项利用不同电刺激强度和表面肌电对运动单位数目进行估计的新技术[20]。每块肌肉只要几分钟，MUNIX分析操作很快，较MUNE来说患者有很好的耐受。我们之前的研究发现，MUNIX可以用于脊髓损伤患者手部第一骨间肌（FDI）的运动单位数目的估计，发现神经损伤后，运动单位数目较性别年龄匹配的正常组显著变少(Li et al., 2015)。

然而，MUNIX得到的指数结果与肌肉发力和运动功能的交互影响关系还不明确，也未见到应用此技术于脑卒中后康复治疗手段的评估。





神经电生理（**Neurophysiology**）与电诊断

Single Fiber EMG（单纤维肌电）





OUR STUDIES 系列研究内容

Study 1: EIM under Muscle contraction (Published)

Study 2: Subcutaneous fat effects on EIM (Published)

Study 3: Spinal Cord Injury of EIM on Biceps (Under Review)

Study 4: Hand Muscles EIM in SCI related to dexterity (Under Review)

Study 5: EIM and Ultrasound on muscle structural parameters on **stroke** (Planning)

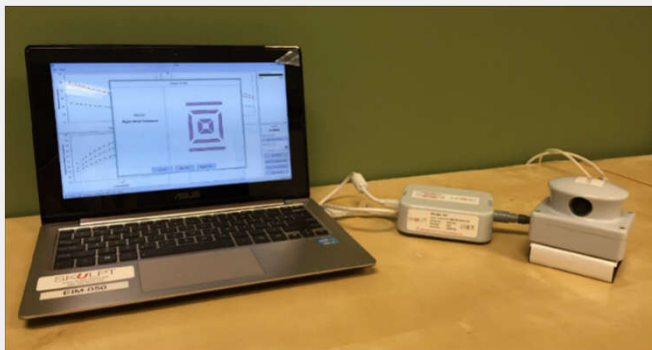
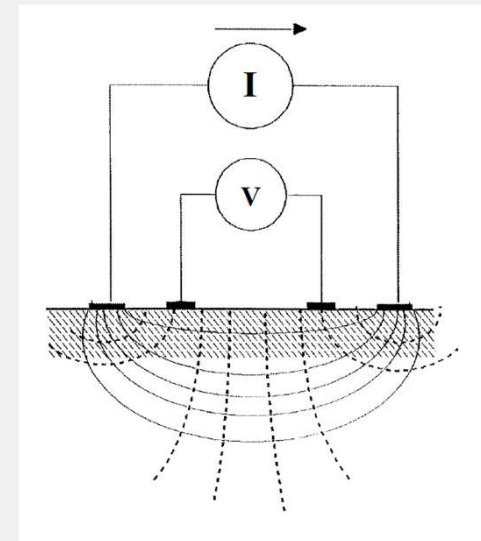
Study 6: Musculotendon modeling parameters of **stroke** survivors correlated with EIM (Future study)





肌肉电阻抗(EIM)技术

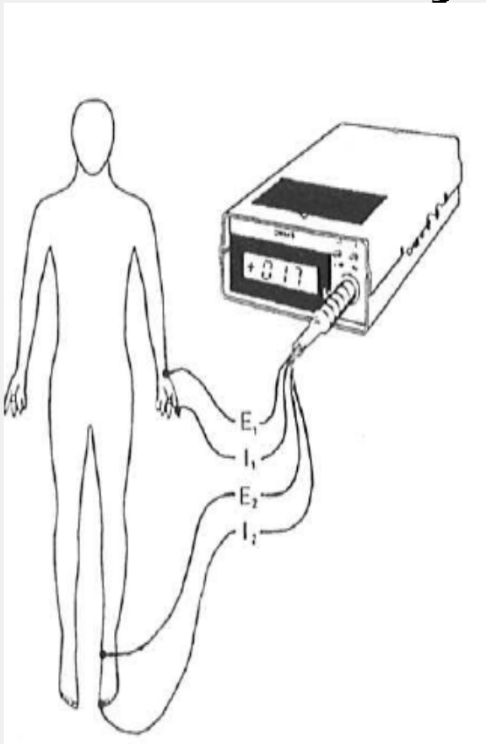
- **Electrical impedance myography (EIM)** is a noninvasive technology to assess muscle health by applying high frequency, very low amplitude current to measure the impedance (resistance and capacitance) of a general muscle volume (Rutkove, 2009).
- It is an electrodiagnostic technique that characterizes the inherent electrical properties of a muscle group.





Where is the technology coming from?

- Bioelectrical impedance Analysis(BIA): A kind of body impedance measurement, focus on body composition and nutrition.



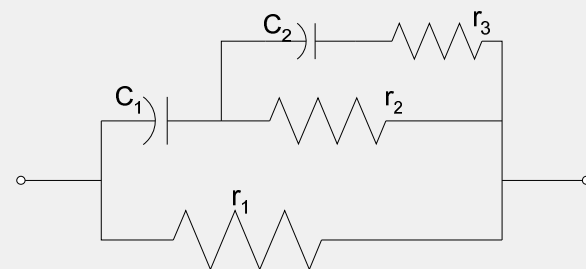


肌肉电阻抗主要参数

Basic EIM parameters include (Esper et al., 2006; Rutkove et al., 2010)

- (1) 电阻 **Resistance (R)**, representing the resistivity to current flow in the extracellular and intracellular fluids;
- (2) 电抗 **Reactance (X)**, indicating how the current flow is affected by cell membranes and by the various fascia of the body, and
- (3) 相位角 **Phase (θ)**, or called phase angle, which is defined as $\theta = \arctan (X/R)$, related to muscle anisotropy, fiber arrangement.

*The broad hypothesis:
Alterations in **composition** and **structure** of
muscle with disease will impact the
electrical impedance of muscle in unique
and reproducible ways.*

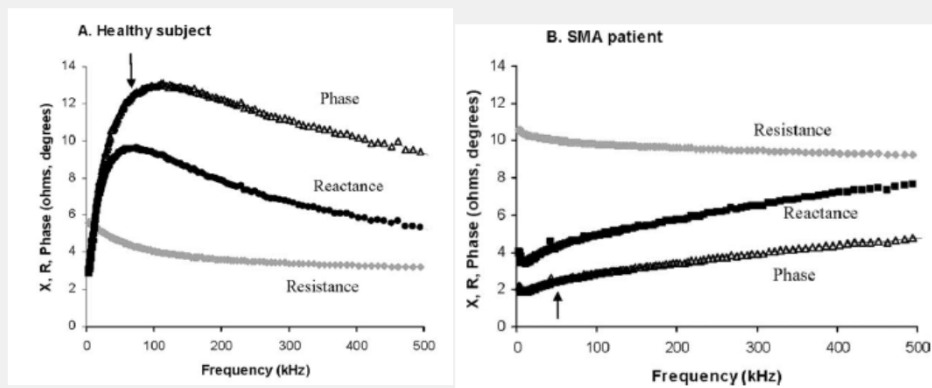


a 5-element resistor-capacitor model

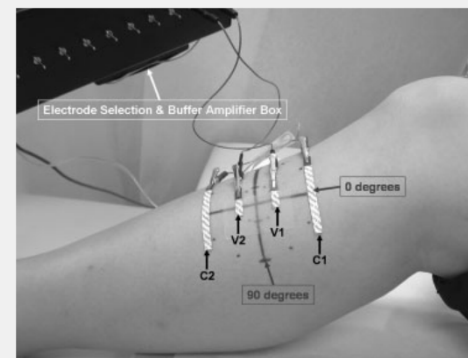


EIM 临床应用

- ❖ Amyotrophic lateral sclerosis(ALS) (Rutkove et al., 2009,2014)
- ❖ Spinal muscular atrophy (SMA) (Rutkove et al., 2010,2012)
- ❖ Duchenne muscular dystrophy (DMD) (Schwartz et al., 2015; Shklyar et al., 2015)



SMA data from Rutkove et al., 2010



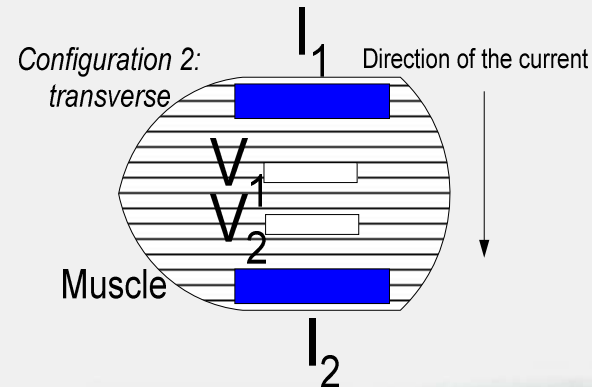
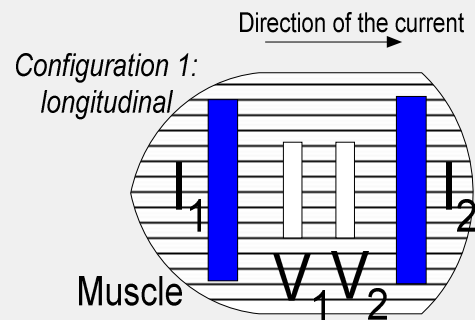
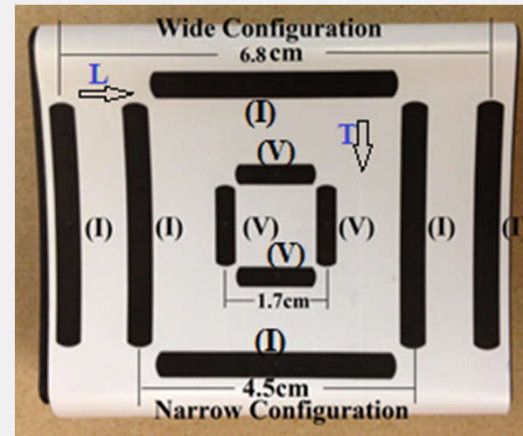


Our Studies on EIM



Method 各向异性研究

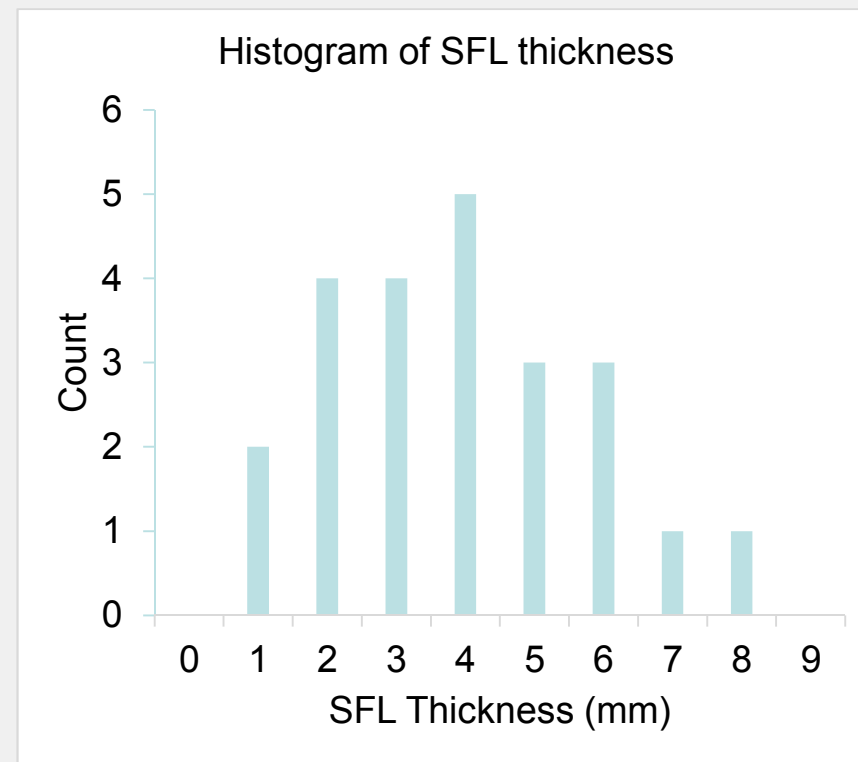
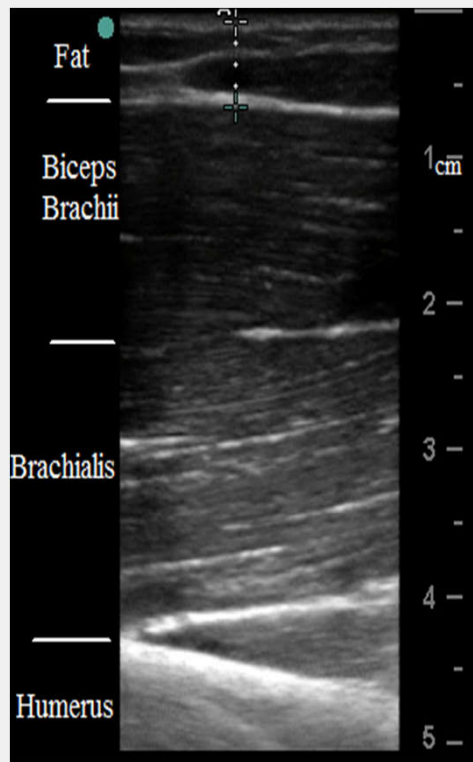
- Twenty-three healthy subjects (11 female and 12 male, age 34.7 ± 7.4 years, ranged from 23 to 46) participated in the study.





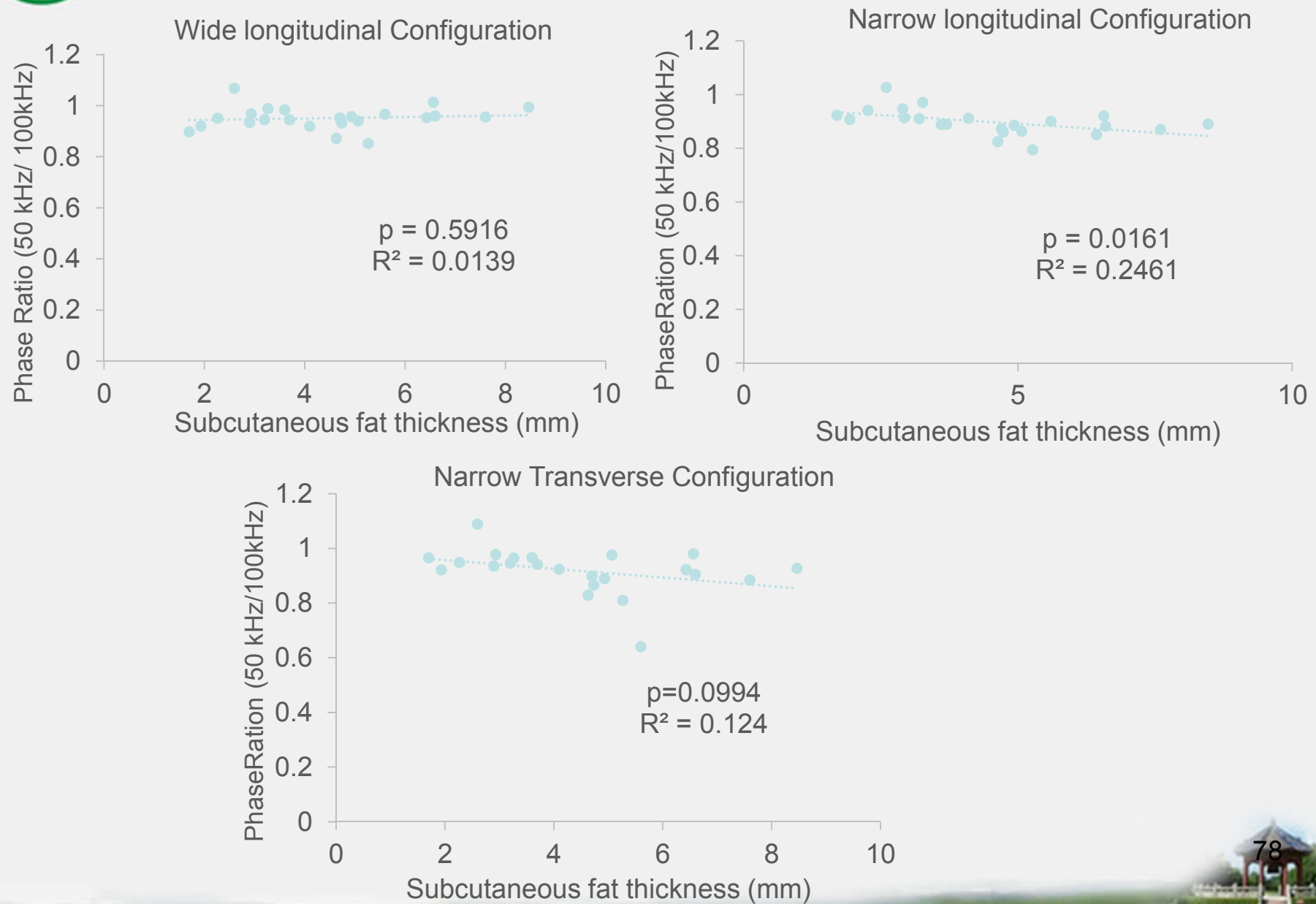
Results

- Ultrasound imaging and Subcutaneous Fat thickness measurement.





Phase ratio





Discussion

- We found that among the three EIM parameters **reactance** is the least affected by the subcutaneous fat.
- Applying transverse current emitting configuration and multi-frequency **phase ratio** can help to reduce the impact of subcutaneous fat on biceps brachii.
- Therefore, these settings should be evaluated when applying EIM in future clinical studies.

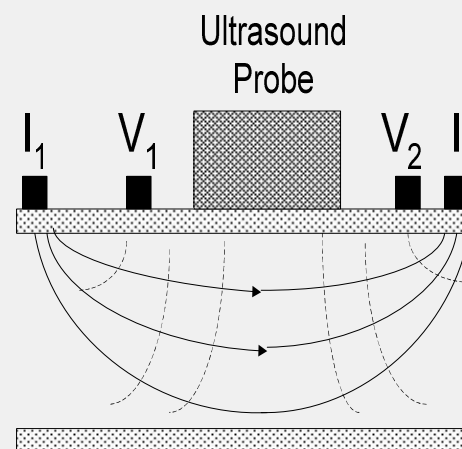
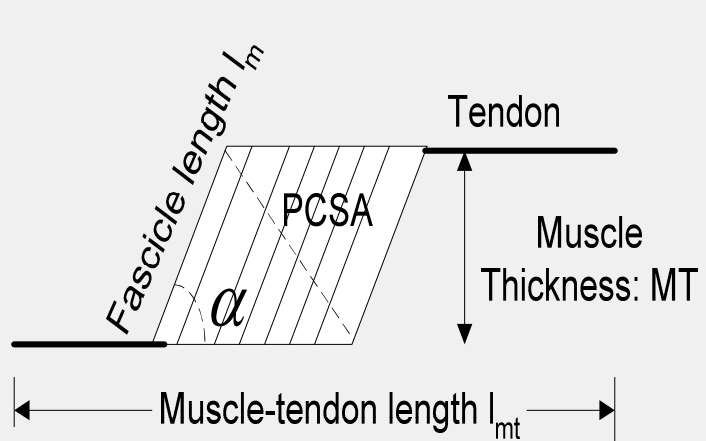


Hypothesis and Question

- Muscle architectural parameters (Pennation angle, fascicle length , muscle thickness) correlated with innate electrical properties?
- How these impedance parameters and structure data related with generated muscle force?
- Electrical and acoustics measurement can be done without interference with each other...

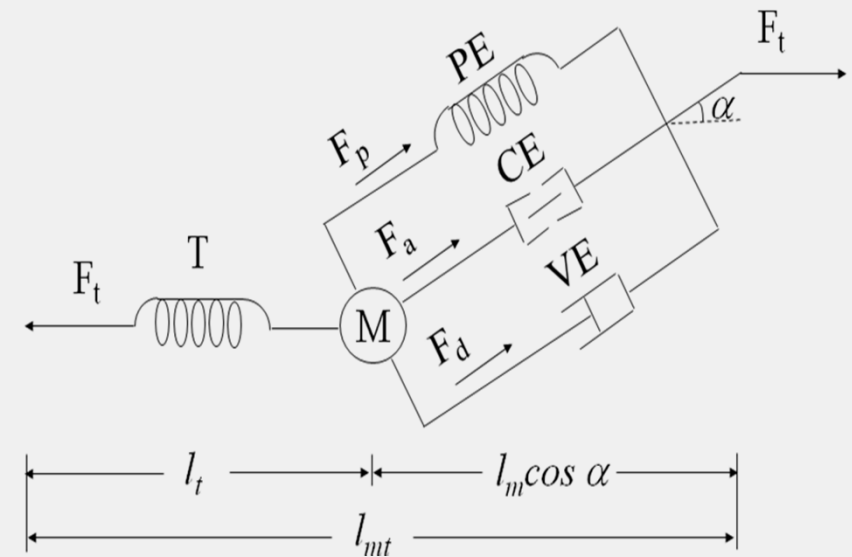
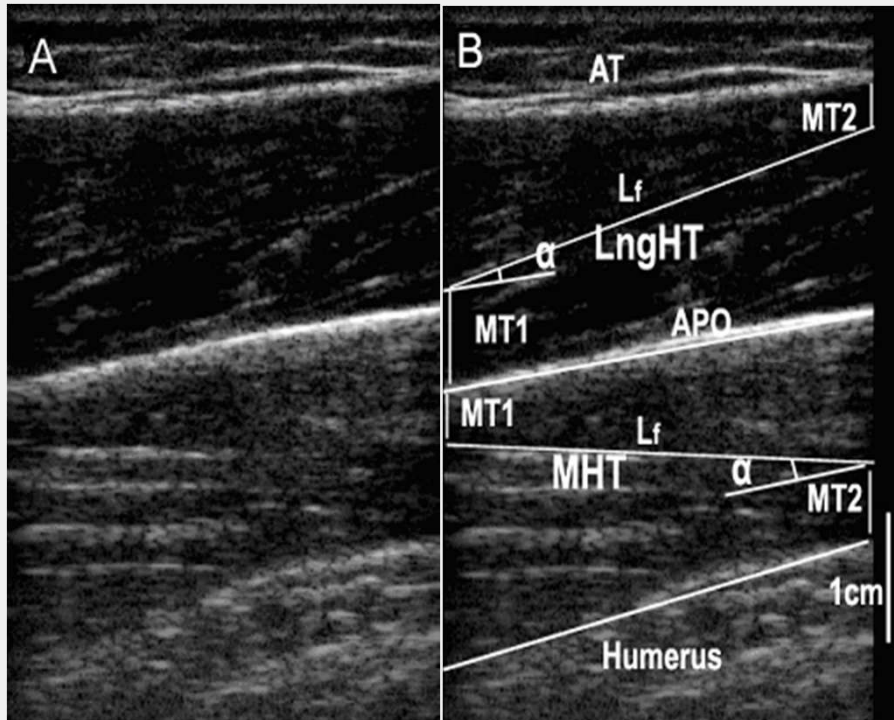


Method





Muscle modeling





结果和结论

- **EIM**可反映肌肉萎缩情况（包括肌肉内脂肪与肌肉组织比例），以及肌肉内的肌纤维走向和排列（各向异性，**anisotropy**），肌细胞膜完整性（**membrane integrity**）等变化
- **EIM**在发力和疲劳下变化
- 皮下脂肪对**EIM**相关参数有影响





Discussion

- We found that among the three EIM parameters **reactance** is the least affected by the subcutaneous fat.
- Applying transverse current emitting configuration and multi-frequency **phase ratio** can help to reduce the impact of subcutaneous fat on biceps brachii.
- Therefore, these settings should be evaluated when applying EIM in future clinical studies.



Summary

- One EIM alone may not provide full picture of what happen.
- EIM on disease progression, time / treatment effects.



Related Publications

- **Li L**, Li X*, Liu J, Zhou P. Alterations in multidimensional motor unit number index of hand muscles after incomplete cervical spinal cord injury. ***Front. Hum. Neurosci.*** 2015;9:238. doi: 10.3389/fnhum.2015.00238 (IF=3.67)
- **Li L**, Li X, Hu H, Shin H, Zhou P*. The Effect of Subcutaneous Fat on Electrical Impedance Myography: Electrode Configuration and Multi-frequency Analyses. ***Plos One.*** 2016;11(5):e0156154. (IF=3.057)
- **Li L**, Shin H, Li X, Li S, Zhou P*. Localized Electrical Impedance Myography of the Biceps Brachii Muscle during Contraction and Fatigue. ***Sensors*** (Basel). 2016. 22;16(4). (IF=2.25)





MUNIX at SCI (Li et al., 2005)

 **frontiers**
in Human Neuroscience

ORIGINAL RESEARCH
published: 08 May 2015
doi: 10.3389/fnhum.2015.00238

Alterations in multidimensional motor unit number index of hand muscles after incomplete cervical spinal cord injury

Le Li^{1,2}, Xiaoyan Li^{2*}, Jie Liu³ and Ping Zhou^{2,4}

¹ Department of Rehabilitation Medicine, The First Affiliated Hospital, Sun Yat-Sen University, Guangzhou, China,

² Department of Physical Medicine and Rehabilitation, University of Texas Health Science Center at Houston, and TIRR Memorial Hermann Research Center, Houston, TX, USA, ³ Sensory Motor Performance Program, Rehabilitation Institute of Chicago, Chicago, IL, USA, ⁴ Biomedical Engineering Program, University of Science and Technology of China, Hefei, China





SF effects on EIM (Li et al., 2016)



RESEARCH ARTICLE

The Effect of Subcutaneous Fat on Electrical Impedance Myography: Electrode Configuration and Multi-Frequency Analyses

Le Li^{1,3,4}, Xiaoyan Li^{3,4}, Huijing Hu^{2,3,4}, Henry Shin^{3,4}, Ping Zhou^{2,3,4*}

1 Department of Rehabilitation Medicine, The First Affiliated Hospital, Sun Yat-sen University, Guangzhou, Guangdong, China, **2** Guangdong Provincial Work Injury Rehabilitation Center, Guangzhou, Guangdong, China, **3** Department of Physical Medicine and Rehabilitation, University of Texas Health Science Center at Houston, Houston, Texas, United States of America, **4** TIRR Memorial Hermann Research Center, Houston, Texas, United States of America



CrossMark
click for updates

* ping.zhou.1@uth.tmc.edu





EIM at contraction (Li et al., 2016)



sensors



Article

Localized Electrical Impedance Myography of the Biceps Brachii Muscle during Different Levels of Isometric Contraction and Fatigue

Le Li ^{1,2}, Henry Shin ², Xiaoyan Li ², Sheng Li ² and Ping Zhou ^{2,3,*}

¹ Department of Rehabilitation Medicine, the First Affiliated Hospital, Sun Yat-sen University, Guangzhou 510080, China; Le.Li@uth.tmc.edu

² Department of Physical Medicine and Rehabilitation, University of Texas Health Science Center at Houston; TIRR Memorial Hermann Research Center, Houston, TX 77030, USA; Henry.Shin@uth.tmc.edu (H.S.); Xiaoyan.Li@uth.tmc.edu (X.L.); Sheng.Li@uth.tmc.edu (S.L.)

³ Guangdong Work Injury Rehabilitation Center, Guangzhou 510440, China

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Academic Editors: Steffen Leonhardt and Daniel Teichmann

Received: 8 February 2016; Accepted: 17 April 2016; Published: 22 April 2016





SFL effects

- Conductivity (σ) and Permittivity (ϵ)
- Conductivity is reciprocal to σ
- Permittivity related tissue's polarizability, to ϵ



Discussion: Behind Data--- What mechanism?

- larger resistance and similar reactance
- similar resistance but smaller reactance
- Smaller resistance, reactance and phase
- increased resistance could be related to muscle atrophy, fat infiltration
- reduced reactance could be due to changes of membrane integrity
- fat infiltration also affects the anisotropy



The John P. and Kathrine G. McGovern Medical School



Thank you!



主要简历

年代	学校	专业/系	学位/工作经历
1996.09-2000.07	西安交通大学	生物医学工程	本科
2000.09-2003.06	西安交通大学	生物医学工程	硕士
2003.06-2007.12	香港理工大学	生物医学工程	PhD
2007.03-2008.06	香港理工大学	生物医学工程	Research Associate
2008.07-2010.08	香港理工大学	生物医学工程	Postdoc Fellow
2010.08-至今	中山大学“百人计划”引进人才		
2014.09-2016-09	美国德州大学健康研究中心& TIRR康复医院 访问学者		



获基金资助的主持课题 (总经费>200万)

1. “肌肉肌腱力学特性改变对脑卒中步态重建的神经肌肉骨骼建模研究”,国家自然科学基金青年基金, 22万, 2012.1-2014.12.
2. “减重步态训练对脑卒中下肢肌肉肌腱影响的超声评估”, 高校基本科研业务费中大医科青年教师培育项目, 15万, 2011.11-2014.10.
3. 2013年度省产学研专项计划 (No. 2013B090500099): 基于肌骨生物力学模型驱动的可穿戴式下肢康复机器人。项目经费: 50万, 2014.12-2017.12
4. 2015年省自然项目 (No. 2015A030313139): 痉挛影响脑卒中上肢运动功能障碍的生物力学机制研究。项目经费: 10万, 2015.8-2018.8
5. 2015年省协同创新与平台环境建设项目 (No.2015A050502022): 脑卒中肌肉形态结构与电阻特性影响运动功能的生物力学机制。 项目经费: 50万, 2016-01-01 至 2017-12-31

人才项目:

1. “脑卒中运动康复”, 中山大学百人计划科研基金, 25万, 2010.9-2013.8



第一作者或通讯作者SCI论文情况

- **Li L***, Tong KY. Combined ultrasound imaging and biomechanical modeling to estimate triceps brachii musculotendon changes in stroke survivors. Biomed Res Int. in press IF=2.134
- **Li L**, Li X, Hu H, Shin H, Zhou P*. The Effect of Subcutaneous Fat on Electrical Impedance Myography: Electrode Configuration and Multi-frequency Analyses. PlosOne. 2016;11(5):e0156154. IF=3.057
- **Li L**, Shin H, Li X, Li S, Zhou P*. Localized Electrical Impedance Myography of the Biceps Brachii Muscle during Contraction and Fatigue. Sensors (Basel). 2016. 22;16(4). IF=2.033
- **Li L**, Li X*, Liu J, Zhou P. Alterations in multidimensional motor unit number index of hand muscles after incomplete cervical spinal cord injury. Front. Hum. Neurosci.2015;9:238. doi: 10.3389/fnhum.2015.00238 IF=3.67
- **Li L**, Wei Rong, Zheng Ke, Xiaoling Hu, Kaiyu Tong. The effects of training intensities on motor recovery and gait symmetry in a rat model of ischemia. Brain Inj., 2013;27(4):408-416. IF=1.36
- **Li L**, Wei Rong, Xiaoling Hu, Zheng Ke, Kaiyu Tong. Muscle activation improvement during treadmill training after focal cortical ischemia: a rat hindlimb model. J Electromyogr Kinesiol. 2011;21:318-326 IF=1.644
- **Li L**, Zheng Ke, Kaiyu Tong, Michael Ying. Evaluation of cerebral blood flow changes in focal cerebral ischemia rats by using Transcranial Doppler ultrasonography. Ultrasound in Med. & Biol, 2010; 36:595-603. IF=2.455
- **Li L**, Kaiyu Tong, Xiaoling Hu, Leungkim Hung, Terry KwokKeung Koo. Incorporating Ultrasound-Measured Musculotendon Parameters to Subject-Specific EMG-Driven Model to simulate voluntary elbow flexion for Persons after Stroke. Clin. Biomech. 2009; 24 : 101-109.IF=1.869
- **Li L**, Kaiyu Tong, Rong Song, Terry KwokKeung Koo. Is maximum isometric muscle stress the same among prime elbow flexors? Clin. Biomech. 2007; 22: 874-883. IF=1.869
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谢谢！

Q & A



Some thoughts

- Saying shear-wave elastography, it is not a direct measurement of muscle mechanical property. Based on several assumptions, it can be used to reveal muscle passive and active tension in an indirect fashion for comparison only in my view.

It can measure passive muscle tension on the longitudinal plane which is the functional direction of muscle rather than vertical plane, while Myoton cannot. Therefore, the direction of transducer relative to muscle fiber axis is crucial.

It can quantify muscle active tension of individual muscle or muscle head, e.g. MG, LG, SOL for TS. The disadvantage is that this can be only used in isometric contraction and for my experience lower than 50% MVC in large muscle group

