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Measuring Spasticity in people with DoC - from the lab to the bed side

Anand Pandyan, Rasheed Meeran, Raymundo (Ray) Milay and Adam Poulter
Keele University
a.d.pandyan@keele.ac.uk

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A plan of sorts

- Spasticity and approaches to measure this
- Is there a reason to change current clinical approaches to measurement
- Measurement challenges in DoC

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Spasticity – a conceptual definition

Disordered sensori-motor control, resulting from an upper motor neurone lesion, presenting as intermittent or sustained involuntary activation of muscles

Pandyan et al 2005 Disabili & Rehab – SPASM consortium

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Spasticity (operational definition)

- Spasm (A transient but continuous muscular contraction with cutaneous or visceral triggers)
- Clonus (A transient but intermittent rhythmic or muscle contraction with proprioceptive and/or cutaneous triggers)
- Stretch induced muscle activity
- *Abnormal movement patterns & co-contraction still remain unresolved*

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Score	Penn spasm frequency scale	Spasm frequency score
0	No spasms	No spasms
1	Mild spasms at stimulation	One or fewer spasms per day
2	Irregular strong spasms less than one time/hour	Between one and five spasms per day
3	Spasms more often than one time/hour	Five to less than 10 spasms per day
4	Spasms more than 10 times/hour	Ten or more spasms per day, or continuous contraction

Table 4: The descriptors associated with the ordinal level scales used to quantify the frequency of spasms.

Penn RD et al 1989 Intrathecal baclofen for severe spinal spasticity. N Engl J Med, 320: 1517 – 1521. Snow BJ et al 1990 Treatment of spasticity with botulinum toxin: a double blind study. Ann Neurol, 28: 512 – 515. Biering-Sørensen et al 2005 Spasticity-assessment: a review. Spinal Cord, 44: 708 – 722.

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Tardieu method for measuring spasticity

Quality of muscle reaction (X):

0 No resistance throughout the course of the passive movement
1 Slight resistance throughout the course of the passive movement, with no clear catch at precise angle
2 Clear catch at precise angle, interrupting the passive movement, followed by release
3 Fatigable clonus (< 10 seconds when maintaining pressure) occurring at precise angle
4 Infatigable clonus (> 10 seconds when maintaining pressure) occurring at precise angle

Gracies et al., 2000, Boyd & Ada 2001, Morris 2002

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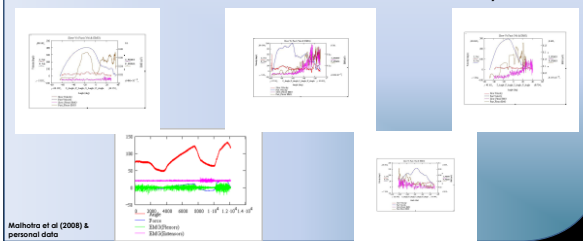
Stretch induced muscle activity



Malhotra et al (2008) & personal data

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Contractures – a definition (& a digression)

A pathological condition of soft tissues **characterised by stiffness** and is usually associated with **loss of elasticity** and **fixed shortening** of the involved tissues (muscle, tendon, ligament, subcutaneous tissue, skin, blood vessels and nerves) and results in **loss of movement around a joint**

Harburn and Potter (1993); Teasell and Gillen (1993); Lehmann et al (1989); Botte et al (1988)

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Does spasticity cause contractures?

Lessons from observing stroke patients with sever levels of disability

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Had no function or spasticity

- Female – 74
- Total Anterior Circulatory Infarct
- NIHSS – 17 (Arm = 4, Leg = 2)

	Pre-Stroke	Admission	Baseline	3 Months	6 Months
Barthel	20	3	11	17	18
ARAT	57	0	0	0	0

EUBOSS (2012 – 2014)

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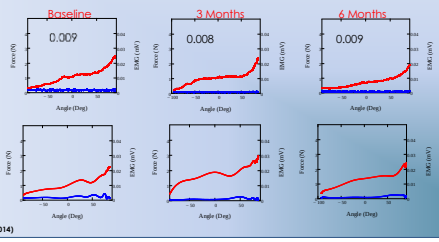
.....did not develop contractures



EUBOSS (2012 – 2014)

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Had no function but developed spasticity

- Male - 81
- Partial Anterior Circulatory Infarct
- NIHSS – 13 (Arm = 4, Leg = 3)

	Pre-Stroke	Admission	Baseline	3 Months	6 Months
Barthel	20	1	4	3	3
ARAT	57	0	0	0	1

EUBOSS (2012 – 2014)

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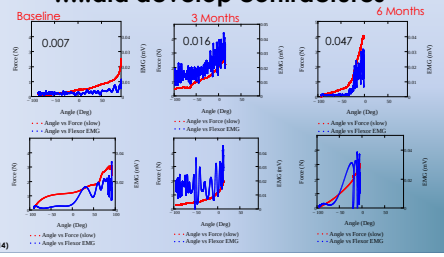
…..did develop contractures



EUBOSS (2012 – 2014)

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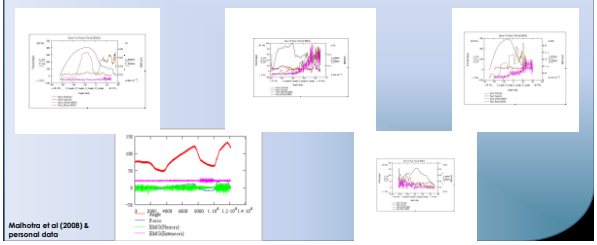
Forms of spasticity and links to contractures



Malhotra et al (2008) & personal data

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A summary of my thoughts on spasticity and contractures

- Spasticity may be an inevitable consequence of a neurological injury
- In patients with no functional movement atrophy is an inevitable consequence
- In patients with no functional movement and spasticity (or spastic dystonia) contractures may be inevitable

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Should we measure stretch induced muscle activity as a measure of spasticity as opposed to using clinical scales?

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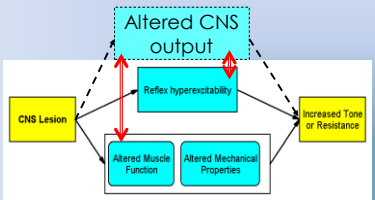
Reason 1: Resistance to passive movement is a confounded measure.



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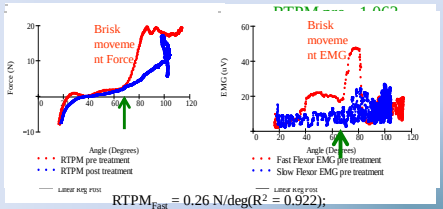

$RTPM_{Fast}$ = 0.26 N/deg(R^2 = 0.922); ($Speed_{Fast}$ = 74 deg/s)

$RTPM_{Slow}$ = 0.22 (R^2 = 0.721) ($Speed_{Slow}$ = 8 deg/s)

e.g. from two responders to treatment with botulinum toxin

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Reason 2: Clinical scales are bad at identifying early spasticity

MAS	Abnormal muscle activity	
	- ive	+ ive
0	12	44
1	0	21
1+	0	12
2	1	3
3	0	6
4	0	1

EMG **MAS**	*With*	*Without*
+ive	43	1
-ive	44	12

Sensitivity = 43/(43+44) = **0.49**

Specificity = 12/(12+1) = **0.92**

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Reason 3: Treatment effects are often missed or underestimated

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PTJ

Quantitative Measurement of Poststroke Spasticity and Response to Treatment With Botulinum Toxin: A 2-Patient Case Report
Elizabeth Cousins, Anthony B. Ward, Christine Roffe, Lesley D. Rimington and Anand D. Pandyan
PHYS THER. 2009; 89:688-697.
Originally published online May 29, 2009
doi: 10.2522/ptj.20080040

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Case Report 1 – Patient A

- 72 year old gentleman
- Had a left MCA infarct with subsequent haemorrhagic transformation 3 days later
- Baseline measures taken 37 days poststroke
- No active movement of upper limb

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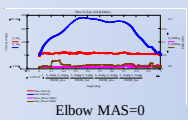
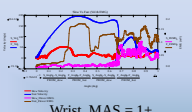
Patient A - baseline



Elbow MAS=0



Wrist MAS = 1+

- Elbow - Very slight velocity dependent response
- Wrist -Marked velocity and position dependent response to passive stretch
- No pain reported
- No active movement at elbow or wrist
- ARAT = 0/57

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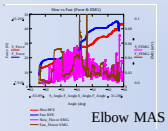
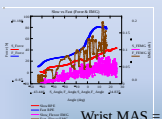
Patient A – Week 4



Elbow MAS = 3



Wrist MAS = 3

- Elbow – position dependent spasticity
- Wrist – velocity and position dependent spasticity
- Moderate pain
- No active movement
- ARAT = 0/57
- BoNTA (total Onabotulinumtoxin 400U) given 5 days after this assessment

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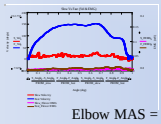
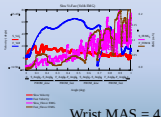
Patient A – Week 8 (&12)



Elbow MAS = 3



Wrist MAS = 4

- Elbow – no spasticity
- Wrist – position dependent spasticity
- Pain "couldn't be any worse"
- No active movement
- ARAT 0/57

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Clinical Rehabilitation 2002; **16**: 654–660

Are we underestimating the clinical efficacy of botulinum toxin (type A)? Quantifying changes in spasticity, strength and upper limb function after injections of Botox® to the elbow flexors in a unilateral stroke population

Anand D Pandyan Department of Physiotherapy Studies, Keele University, **Philippe Vuadens** Clinique Romande de Readaptation, Sion, Switzerland, **Frederike MJ van Wijck** Centre for Rehabilitation and Engineering Studies (CREST), University of Newcastle, **Sandra Stark** Hunters Moor Regional Neurological Rehabilitation Centre, Newcastle upon Tyne, **Garth R Johnson** and **Michael P Barnes** Centre for Rehabilitation and Engineering Studies (CREST), University of Newcastle, Newcastle upon Tyne, UK

Received 22nd March 2001; returned for revisions 15th May 2001; revised manuscript accepted 21st June 2001.

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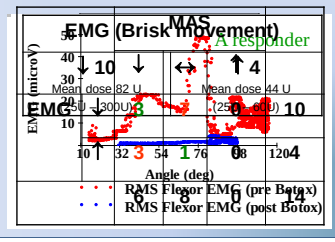

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Reason 4: Clinical interpretation of the term spasticity is not consistent (lessons from observations on a child scheduled for SDR)

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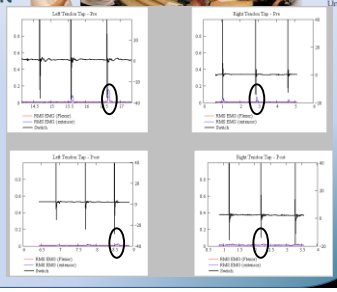
Lower limb reflexes appear normal pre-surgery



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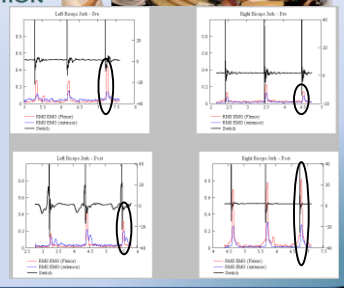
Upper limb reflexes appear normal pre-surgery (possibly a wind up phenomenon)



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Lower limb pendulum (left) appear normal pre-surgery

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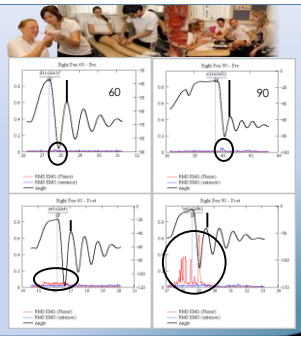
Lower limb pendulum (right) appear normal pre-surgery



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Measuring spasticity in DoC

BACKGROUND

- Holy Cross Hospital (HxH): 40 beds - 18 are in Disorders of Consciousness (DOC).
- Majority of patients in HxH suffer with spasticity.
- Current rx….
- Modified Ashworth Scale (MAS) – measuring tool for spasticity.
- Problem –difficult to reproduce, inter-rater reliably *(1)*.
- Lacks sensitivity – basic assessment tool for a complex issue.

AIMS/OBJECTIVES

- Is the Biometrics Ltd. DataLog MWX8 accurate, reliable, and practical in measuring spasticity in a clinical setting?
- Can these methods of measurement inform clinical decision making?

PATIENT GROUP

- Vegetative State
- Diagnosed with TBI or Hypoxic Brain Injury
- Unilateral or bilateral elbow flexor spasticity/stiffness.
- MAS score ≥ 1 elbow flexors
- Able to be seated for measurement purposes

PATIENTS SELECTED

- **A sample of 3 patients.**
- **Patient 1 – Botulinum Toxin A Injection**
  - The patient has had regular botulinum toxin injections in the past to treat the elbow flexor spasticity.
  - The patient had a course of injections during the surface EMG measurement period.
- **Patient 2 – Splint Intervention**
  - The patient has bilateral fibreglass elbow splint to control bilateral elbow flexor stiffness.
  - The patient has had BoNT-A injections in the past for the elbow flexors but is 4 months post injection during the period of surface EMG measurements.
- **Patient 3 – Passive stretching regime**
  - The patient has had BoNT-A injections in the past for the left elbow flexors but is 4 months post injection during the period of surface EMG measurements.
  - The patient is only receiving manual passive stretching regime to maintain elbow range.

MEASUREMENTS

Pre-measurement protocol:

- No infection.
- Trache care/suction 30 mins prior.
- Sat out for minimum 1 hour before measurements.
- Patient should be settled and not agitated (as much as possible).
- Measurements completed in wheelchair.
- Pillows and lateral support removed.
- Electrodes applied to motor points as per BoNT-A injection manual.
- Measurements completed in the physio gym.

MEASUREMENTS CONTINUED....

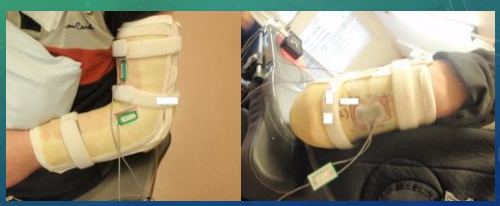
Same protocol for all patients before and after intervention.

Six channels to be used:

- Channel 1: Biceps brachii EMG through metal electrodes.
- Channel 2: Brachioradialis EMG through metal electrodes.
- Channel 3: Triceps EMG through metal electrodes.
- Channel 5: Stretch force applied through force transducer.
- Channel 6: Joint angle measurements through angle sensor.
- Ground channel.

EXAMPLE OF MEASUREMENT SETUP

MEASUREMENT SETUP FOR SPLINTING CONDITION



STANDARD MEASUREMENTS FOR ALL PATIENTS

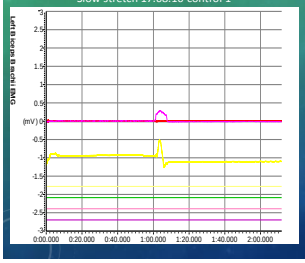
- **Measurement 1**
  - Passive **slow stretch** (roughly 10 seconds from resting position to end range)
  - 1 minute baseline without stimulus -> slow stretch to end range-> release -> record for a further 1 minute.
- **Measurement 2**
  - Passive **fast stretch** (roughly 5 seconds from resting position to end range)
  - 1 minute baseline without stimulus -> fast stretch to end range-> release -> record for a further 1 minute.
- **Slow stretch always completed prior to fast stretch.**

ADDITIONAL MEASUREMENTS

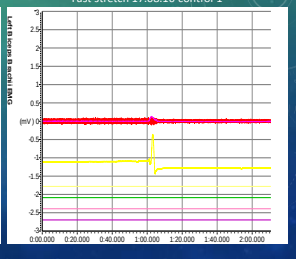
- **Patient 1:**
  - Measurements obtained pre- BoNT-A injection.
  - Measurements 7-14 days post BoNT-A injection and 1 month
- **Patient 2:**
  - Measurement 1+2 pre-application of elbow splint.
  - Applied splint.
  - 5 min measurement of channels 1-3 (Immediately after splint application)
  - 2 hourly 5 min measurements (channels 1-3) for a period of 4 hours.
  - Repeat measurement 1+2 immediately after removal of splint.
- **Control group:**
  - Measurements obtained from staff

NORMAL SUBJECTS

Slow stretch 17.08.16 control 1

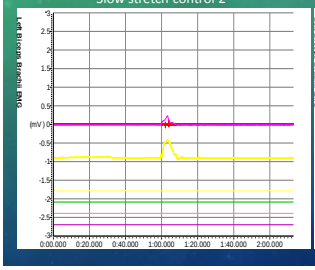


Fast stretch 17.08.16 control 1

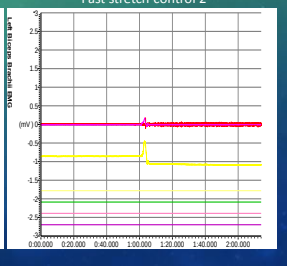


NORMAL SUBJECTS

Slow stretch control 2



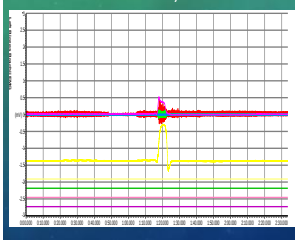
Fast stretch control 2



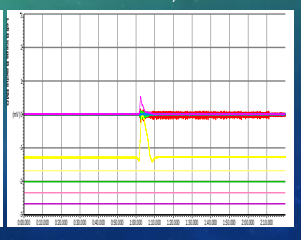
PATIENT 1 RESULTS

COMPARING PRE AND POST BOTOX

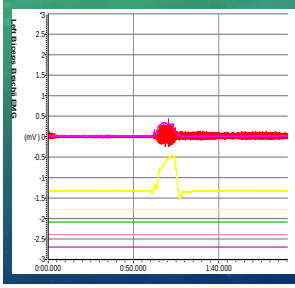
Pre Botox 29/06/16 (fast stretch)



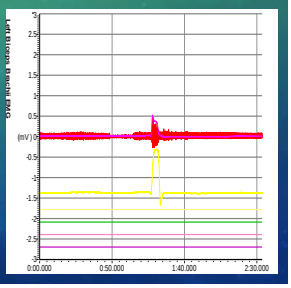
Post Botox 25/07/16 (fast stretch)

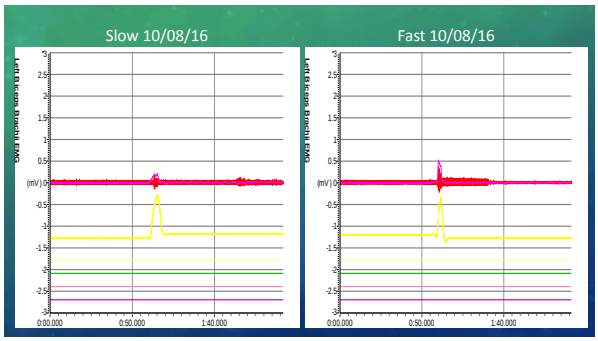


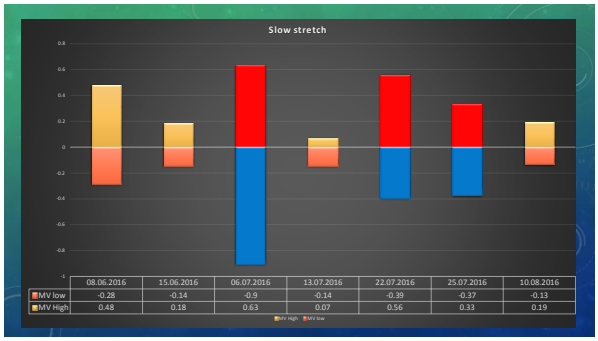
Slow stretch 29/06/16



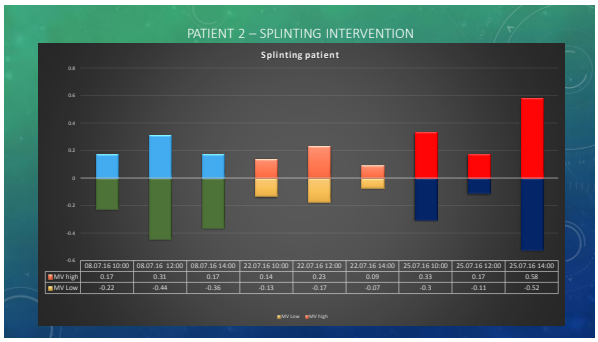
Fast stretch 29/06/16







PATIENT 2 RESULTS



PATIENT 3 RESULTS

GRAPHS FOR PATIENT 3

CONCLUSIONS

- Following injections on BoNT-A amplitude was reduced
- Not all patients are demonstrating spasticity – see patient 2, should they have had Botox?
- Low arousal demonstrates a reduced amplitude in EMG readings.
- We are not able to effectively assess splinting with the current technology.
- Can measure for 20 minutes in splinting condition – longer periods may cause marking/sores.
- Some of the background artefacts on the readings – are these due to methodology or fibrosis/adipose tissue.
- No demonstration of "catch" (patient 3) on graphs despite being rated MAS 1

LIMITATIONS

- Initially took 1 hour to complete readings.
- Extensive practice and training required for specific protocol and use of equipment.
- To monitor effect of splinting a patient's splint had to be modified to fit electrodes without splint removal.
- Requires certain conditions to gain useful readings, i.e. patient alert, trache care completed, no coughing.
- Connectivity issues - need to use laptop to check settings before reading.
- Difficult to transfer data if collected on SD card – mostly due to IT security in hospitals (cannot use USB or card reader).
- Often if left unattended the laptop would go into standby, causing the Bluetooth signal to be lost.

IMPLICATIONS FOR PRACTICE

- Reduced application to measurement time to 15-20 mins per limb
- Useful as an adjunct to MAS to review individual muscle groups.
- Can be completed in sitting with one therapist but much faster with two.
- Can give more specific results over time and give a numerical objective value.
- Useful in clinical decision making regarding BoNT-A injections – spasticity vs contracture.
- Better equipment:
  - Wireless electrodes, goniometer and force transducer – facilitate set up and ease of measurement
  - Bluetooth connectivity issues – loss of connection, unable to transfer data wirelessly
  - Datalog software compatibility – only runs on Windows 7

FUTURE RECOMMENDATIONS

- Re-test muscle groups where there are anomalies (yawning or low arousal).
- A longer (4-6 hours) reading may be of benefit in the splinting condition, however we were limited by marking on the skin due to the electrodes.