Multimodal analysis –
High speed multimodal imaging and analysis of skeletal muscle contraction

Skeletal muscle contraction is initiated by an action potential, followed by shortening and thickening of the cell, and consumption of oxygen, and these mechanisms can be monitored by electromyography (EMG) (Karlsson et al. 2009), ultrasound, and near-infrared spectroscopy (NIRS), respectively. Since the contraction process is a transient phenomenon, sampling rates in the kHz range is required to obtain full information on the process. Information on skeletal muscle contraction using ultrasound and NIRS has been shown to provide complementary information to EMG (Grönlund et al. 2013; Lindkvist et al. submitted). The aim of this work is to analyse the joint electrical, mechanical and biochemical dynamics during the muscle contraction process.

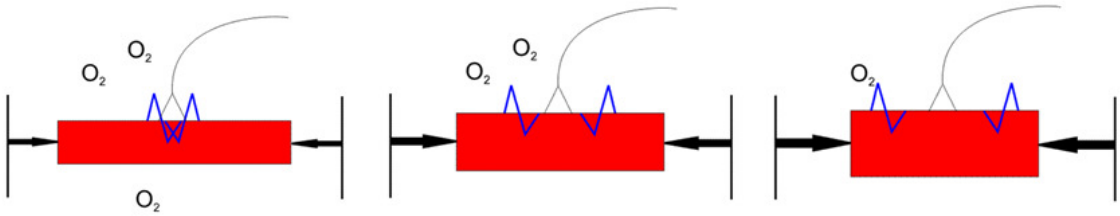
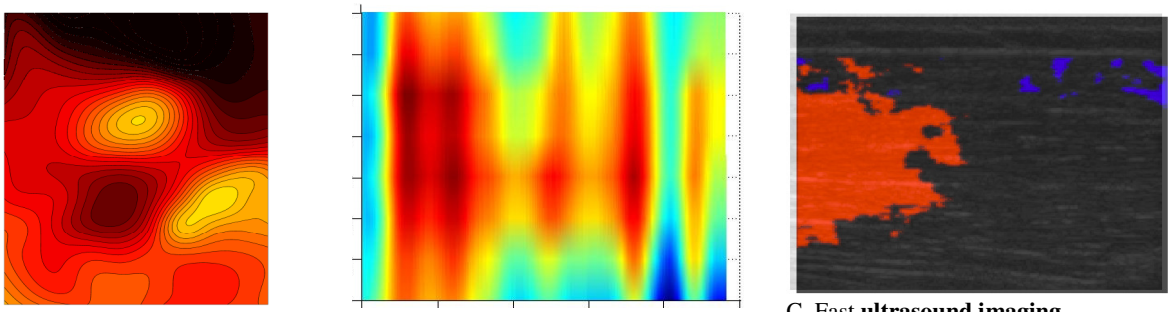


Figure 1. *Illustration of the skeletal muscle contraction (at three consecutive time instants, left to right) comprising electrical action-potential propagation (blue), mechanical thickening and shortening of cell (red), consumption of oxygen, and force production (arrows).*



A. High Density **EMG Imaging** B. High speed **NIRS Imaging**. C. Fast **ultrasound imaging**

Figure 2. *A) High Density EMG imaging. Image of the electrical potentials on the surface of the skin during muscle contraction. B) NIRS, Oxygen concentration image lines (y-axis) vs time (x-axis). Red color is high and blue is low concentration. C) Ultrasound imaging. Tissue velocity map is overlaid on colour on B-mode image.*

High density electromyographic imaging: A modified ActiveOne device (Biosemi, The Netherlands) with 2kHz sampling frequency and a grid of 13 by 10 electrodes covering 6 x 4.5 cm.
Ultrafast ultrasound imaging: Customized transmit and receive sequences was used to obtain very high frame rate images at 2 kHz and full field-of-view. Implemented on a SonixTouch system (Ultrasonix Medical Corporation, Canada) and L14-5 linear probe. This allows to image mechanical waves in the tissue (Grönlund et al., 2013).
Near-infrared imaging: Custom-built multichannel open architecture NIRS system (CMTS, Umeå University, Umeå), set up to capture a image line at 2 kHz image rate (Lindkvist et al. submitted).

The simultaneous information attained from these techniques will enhance the understanding of how the neuromuscular system is affected in neuromuscular disorders. Although the different techniques that are to be applied already exist, they are at present not all optimal to be used on skeletal muscles (FUS) or to include the spatial heterogeneity of muscles (mcNIR) and no processing methods exist at this very moment to integrate these results into interpretable datasets.