

# Magnetic Resonance Elastography of the Cerebellum

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## Introduction:

The cerebellum provides vital functions for the human body, and is affected by both neurodegenerative disorders and injury. In the case of neurodegeneration, the disease processes may result in changes to the mechanical behaviour of the tissue. Understanding and modelling neural injury also requires an accurate knowledge of the mechanical response of the tissue to high strain rate loading. There is thus significant motivation for studying the mechanical properties of the cerebellum, and novel techniques for measuring cerebellum viscoelasticity *in vivo* are a valuable adjunct to more traditional *ex vivo* techniques. Several research groups have used MR elastography to characterise the mechanical properties of the human brain (e.g. [1-3]). However all of these studies have focussed on the cerebral hemispheres. There are currently no data in either the rheological or imaging literature for cerebellum mechanical properties. The aim of this study was to provide the first measurements of cerebellum mechanical behaviour, and to compare these properties with the cerebral hemispheres. The fine ultrastructure of the cerebellum led us to hypothesise that the cerebellum would be softer than the rest of the brain.

## Methods:

Eight healthy human volunteers (aged 21-43 years) underwent brain MR elastography for this study. The imaging sequence and data processing methods used in previous studies were adopted for this study [1]. Vibration at 80Hz was produced in the brain through a custom-moulded mouthguard coupled to two driving coils. The transducer was driven by a pulse generator triggered by the MRI spectrometer (Philips Achieva, 3TX, Best, The Netherlands), in order to allow the synchronisation of the MRI pulse sequence with the mechanical wave. A modified spin-echo sequence with an oscillating bipolar gradient applied in the direction of data acquisition acquired the displacement wave at 8 phases during each vibration cycle. Images were collected in the coronal plane, with the imaging stack centred in the cerebellum. Imaging parameters were: matrix 64x64, TE/TR=50/700ms, 7 slices, FOV=192x192, 3mm slice thickness. A matching T2 weighted anatomical image set (256x256) was also collected for ROI selection. Data were processed offline using techniques previously described [1, 4], that solve the wave equation after removing the contribution of the compressional component. Mean storage and loss moduli ( $G'$ ,  $G''$ ) for the cerebral hemispheres, excluding the ventricles, and the cerebellum were calculated, and compared using a paired t-test.

## Results:

The results show that the cerebellum is significantly softer than the cerebrum (t-test,  $p < 0.001$ ), in terms of shear elasticity ( $G'$ , cerebrum  $2.22 \pm 0.28$  kPa; Cerebellum  $1.72 \pm 0.15$  kPa), but there is no significant difference in viscous properties ( $G''$ , cerebrum  $0.99 \pm 0.25$  kPa; Cerebellum  $0.95 \pm 0.14$  kPa  $p > 0.4$ ). An example anatomical image and matching maps of the storage and loss moduli are shown in Figure 1. Figure 2 shows the mean storage and loss moduli for the cerebellum and cerebrum for all subjects.

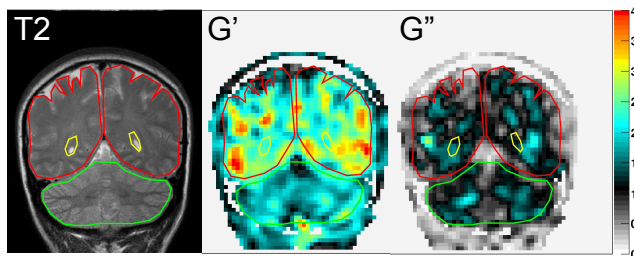


Figure 1. Example Anatomical image, Storage modulus ( $G'$ ) and loss modulus ( $G''$ ) maps. Units are kPa.

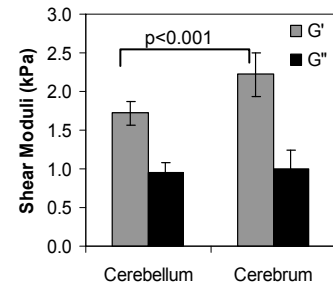


Figure 2. Shear moduli for cerebral hemispheres and cerebellum

## Discussion:

This study provides the first mechanical measurements of cerebellum mechanical properties, in either human or animal. These data show that there is a significant difference in stiffness, with the cerebellum having a lower shear storage modulus than the cerebrum. These data not only provide useful baseline normative data for healthy human cerebellum mechanical behaviour, that can be used for comparing with pathologies that affect the cerebellum, but will also provide much needed information for computational modelling of traumatic brain injury and surgical procedures, which have so far assumed that the cerebellum is similar to the cerebral hemispheres.

## References:

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