A strain analysis of the lower leg during ankle rotation using HARP at 3 Tesla.

M. A. Green[1], S. C. Gandevia[1], and L. E. Bilston[1]
[1]Prince of Wales Medical Research Institute, Sydney, New South Wales, Australia

Introduction

The biomechanics of the muscle-tendon system containing the medial and lateral gastrocnemius and soleus muscles are not altogether well known in terms of the comparison of overall length change and fascicle changes. Moreover, for these muscles the relatively large changes in tendon length across the range of motion of the ankle cannot be explained by tendon tension, fibre pennation or contraction of the muscles (1). Harmonic Phase (HARP) imaging (2,3) is adapted to image the muscle tendon unit for strain estimation across the normal range of motion under passive conditions. Utilising a full body 3T scanner, the study aims to further develop the technique and provide further information on the muscle tendon unit of the lower leg.

Methods

A MR compatible foot plate device has been constructed for the application of the HARP imaging technique. The muscle motion is provided by manually shifting rotating the foot about the ankle in 10 degree increments at a fixed knee angle. Images were acquired under passive conditions to healthy volunteers in the sagittal plane on the Philips 3T system with C-SPAMM (4) tag implementation, using surface coils, 8 mm tag separation, 230 mm FOV, 7 imaging phases, 256x256 matrix, TR/TE = 2.2 msec/1.0 msec, and total scan duration was about 1600 ms. Harmonic phase images were obtained which correspond to spectral peaks and subsequent principal strain measurements were calculated based on peak finding software (5).

Results

Obtaining images for healthy volunteers before and after muscle motion obtained via the HARP imaging technique has enabled principal strain calculation (Figure 1). Principal strains were obtained for all volunteers across the normal ankle range for plantarflexion and dorsiflexion. Regions of interest were specified from the constructed strain maps to give an average value for the medial gastrocnemius and soleus muscles. Principal strain directions were also calculated for each data set.

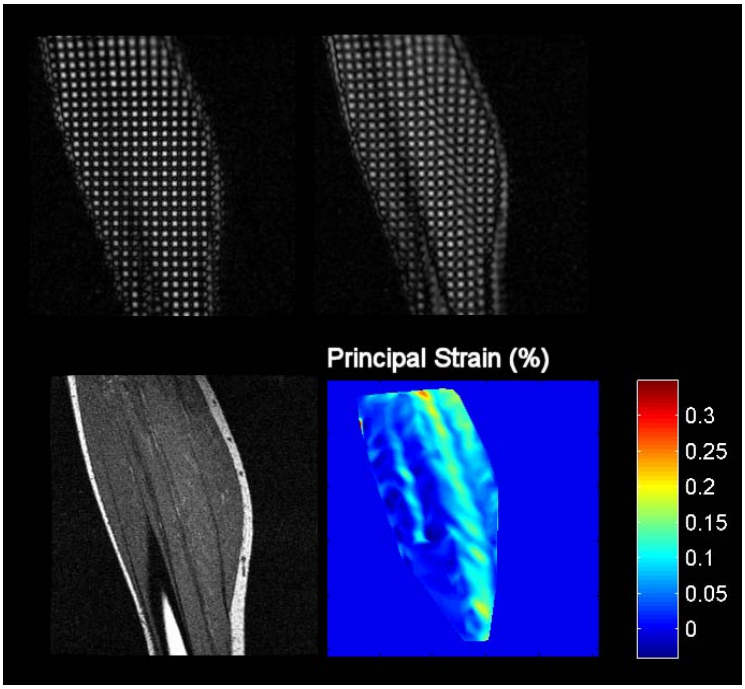

Figure 1: The top images show the initial undeformed tagged image (left) and the deformed image (right) after a of 10° dorsiflexion about the ankle. The sagittal plane through which the tagged images were taken is shown in the T2 weighted image in the bottom left and the bottom right image is a reconstructed principal strain map with large strains occurring in the medial and gastrocnemius.

Discussion

Initial measurements have yielded principal strain magnitudes and directions in the gastrocnemius and soleus about the normal ankle angle range for both plantarflexion and dorsiflexion. The HARP imaging technique in combination with strain determination provides a good quantative assessment of in-vivo distal leg muscle strains and may provide information on intramuscular properties such as muscle fascicle direction.

References

1. Herbert RD, Moseley AM, Butler JE, Gandevia SC. J Physiol 2002;539(Pt 2):637-645.
2. Osman NF, Kerwin WS, McVeigh ER, Prince JL. Magn Reson Med 1999;42(6):1048-1060.
3. Osman NF, McVeigh ER, Prince JL. MRI. IEEE Trans Med Imaging 2000;19(3):186-202.
4. Fischer SE, McKinnon GC, Maier SE, Boesiger P. Magn Reson Med 1993;30(2):191-200.
5. Galindo PL, Kret S, Sanchez AM, Laval JY, Yanez A, Pizarro J, Guerrero E, Ben T, Molina SI. Ultramicroscopy 2007;107(12):1186-1193.