MEASURING CONTINUOUS CHANGES IN HUMAN MUSCLE LENGTH, IN VIVO, USING ULTRASOUND

[1] Ian Loram, [2]Constantinos Maganaris and [1]Martin Lakie
[1]The University of Birmingham, UK, email: i.d.loram@bham.ac.uk
[2]Manchester Metropolitan University, UK; email: c.n.maganaris@mmu.ac.uk

INTRODUCTION

Muscle length is a key variable in the understanding and modeling of musculoskeletal dynamics. Direct, continuous measurement of changes in muscle length has traditionally been achieved using animal preparations and invasive methods (e.g. microsonography) in which the muscle and tendon are exposed. There has been no technique for measuring continuous changes in muscle length in humans or animals *in vivo* in a non-invasive manner. Ultrasonography has been used for several years to measure discrete changes in tendon length and aponeurosis length. We have recently developed this technique to continuously track naturally occurring changes in muscle length as small as ten microns [1, 2]. Here we use externally applied perturbations to investigate the spatial and temporal resolution of the technique.

METHODS

Six subjects stood on a footplate that independently measures left and right ankle torque. The subjects were strapped to a vertical back board while they maintained a low, constant level of ankle torque (~ 5 Nm). Every 1.3 s a pneumatic actuator applied a rapid, square pulse, dorsiflexing ankle rotation of defined magnitude and 0.2 s duration to the left ankle joint.

An ultrasound scanner (DIASUS, UK) recorded 40 s (1200 frames, 29 rotations) of sonographs focused on the distal aponeurosis of soleus and gastrocnemius medialis (Figure 1). In subsequent analysis, image markers were placed on the proximal and distal aponeurosis of the two muscles. Spatial cross correlation was used to track the changes in position of these markers throughout the 1200 frames. From the movement of these markers continuous changes in the length of the muscle were calculated from the differential movement between proximal and distal markers along the line of the central, distal aponeuroses [1]. All 29 rotations were averaged and the step changes in footplate angle and muscle length were measured.

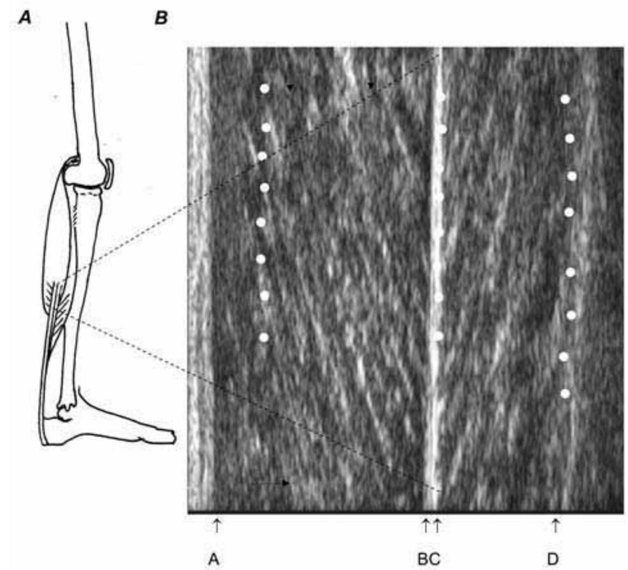

Figure 1: **A** Postural muscles soleus and gastrocnemius, **B** Sonograph showing marker positions (white dots) used for tracking changes in length of the contractile element. A, D proximal aponeuroses of gastrocnemius and soleus. B, C distal aponeuroses which are continuous with the Achilles tendon

RESULTS AND DISCUSSION

The applied ankle rotation and corresponding step increases in muscle length are recorded in Table 1. The ankle rotations are several tenths of a degree which is comparable with the size of rotations that occur naturally during human standing. Changes in gastrocnemius muscle length range from 8 to 300 microns and increase systematically with the size of the ankle rotation. The temporal and magnitude agreement between the measured changes in muscle length and the applied ankle rotations is evidence that the ultrasound tracking technique is recording real changes in contractile element length.

CONCLUSIONS

This technique is non invasive and can measure changes in muscle length with high spatial and temporal resolution. It promises new insights into the study of muscle activity that is difficult to assess using surface EMG where muscles are close together or are relatively deep, or where tendon compliance and motion across multiple joints complicates knowledge of the changes in muscle length.

REFERENCES

1. Loram ID, et al. *J Physiol*, **in press**, 2005.
2. Loram ID, et al. *J Physiol* **556**, 683-689, 2004.

Applied ankle rotation (deg)	0.03 ± 0.003	0.16 ± 0.005	0.30 ± 0.01	0.42 ± 0.02	0.5 ± 0.03
Changes in muscle length (μm)	8 ± 3	43 ± 6	92 ± 17	194 ± 28	300 ± 18
Ratio (μm deg^{-1})	354 ± 156	269 ± 31	306 ± 56	458 ± 60	570 ± 32

Table 1: Changes in gastrocnemius contractile element length in response to ankle rotation. Mean ± S.E.M.