RELATIVE MOTION OF THE RECTUS FEMORIS AND VASTUS INTERMEDIUS DURING KNEE EXTENSION

Deanna Asakawa[1,3], Silvia Blemker[1], Garry Gold[2,3], and Scott Delp[1]

Departments of [1]Mechanical Engineering and [2]Radiology, Stanford University
[3]Diagnostic Radiology Center, Palo Alto VA Health Care System, Palo Alto, California
Email: djasakawa@stanford.edu Web: www.stanford.edu/group/nmbl

INTRODUCTION

The long-term goal of our work is to understand the function of the rectus femoris muscle before and after surgical transfer of its distal tendon. In this surgery, the tendon of the rectus femoris is detached from the patella and reattached behind the knee. The surgery is performed in persons with cerebral palsy who walk with stiff-knee gait, and is thought to convert the muscle from a knee extensor to a knee flexor to assist in knee flexion during walking (Perry, 1987). However, stimulation of the muscle after surgery has revealed that it does not generate a knee flexion moment (Riewald and Delp, 1997). It is possible that scar tissue formed after surgery adheres the rectus femoris to the vastus intermedius and does not allow independent motion of the two muscles. Consequently, the ability of the rectus femoris to transmit force to its tendon and generate knee flexion could be compromised.

As a first step, we examined the relative motions of the rectus femoris and vastus intermedius in subjects with no surgical history. These two muscles share a common distal tendon, but the proximal regions are separated by a fascial plane. We hypothesized that in the absence of scar tissue the rectus femoris and vastus intermedius slide relative to one another during extension of the knee. Futhermore, because the rectus femoris inserts more anteriorly on the patella, we expected this muscle to displace more than the vastus intermedius. The purpose of this study was to test these hypotheses by measuring the displacements of the rectus femoris and the vastus intermedius muscles during knee extension in unimpaired subjects.

METHODS

We used cine phase-contrast magnetic resonance imaging (cine-PC MRI), a dynamic imaging technique, to capture muscle tissue velocity *in vivo* (Pelc et al., 1991; Pappas, 2000). One magnitude image and three velocity images (x, y, and z directions) are acquired for each time frame in a cine-PC MRI movie. Cine-PC MR images of the lower limb were acquired from 3 unimpaired subjects (age: 25-32 yrs, height: 5’ 5” - 5’6”, 2 female, 1 male) with a 1.5T GE scanner. The subjects were positioned supine with the thigh supported in 40° of hip flexion. Subjects were imaged as they actively moved their knee through 100 repeated cycles of knee extension/flexion from approximately 65° of flexion to near full extension at a rate of 35 cycles/min. A second set of images was acquired as the investigator moved the subject’s relaxed leg. All images were acquired in the sagittal plane with a 17ms TR, 36 x 27 cm field of view, and 256x128 matrix with 24 time frames representing a complete motion cycle.

The displacement of square regions of interest in the mid-thigh portion of the rectus femoris (RF) and the vastus intermedius (VI) muscles (Fig. 1) were calculated by integrating the velocity image data (Zhu et al., 1996). We compared the displacements in RF to displacements in VI to assess the relative motion of these muscles.

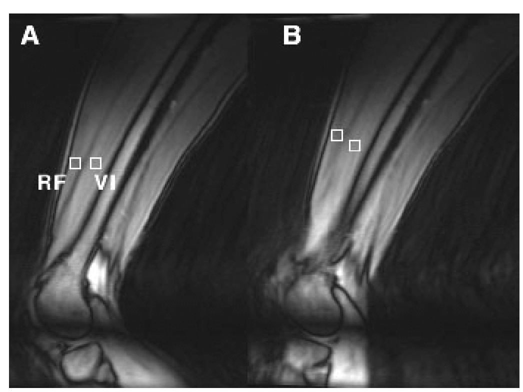

Figure 1. Sagittal plane cine-PC MR images of the thigh. Positions of 1-cm square tissue regions (white boxes) depict displacement of RF relative to VI during active extension from maximum flexion (A) to maximum extension (B).

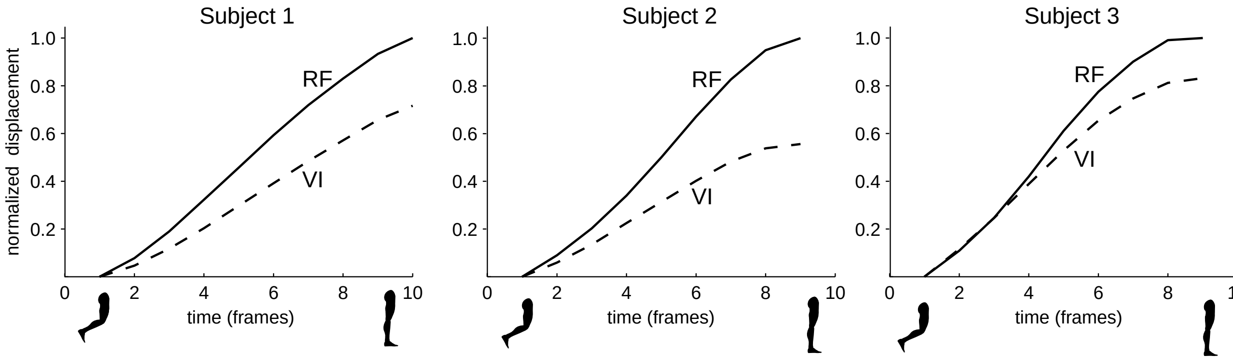

Figure 2. Displacements of the regions of interest within the rectus femoris (RF) and vastus intermedius (VI). Time frame 1 represents approximately 65° of knee flexion and time frame 10 represents the maximum knee extension achieved by the subjects. Displacements were normalized by peak RF displacement during active knee extension.

RESULTS

Displacements of the regions of interest were greater in the RF than in the VI (Figure 2). The maximum displacements of the RF during active extension were 2.1 cm (subject 1), 2.6 cm (subject 2), and 2.4 cm (subject 3). The VI displaced 17-44% less than the RF. When the subjects were moved by the investigator, the displacement trends were similar to the active case, with slightly reduced displacements. The maximum displacements of the regions of interest in RF for the passive motion case were 1.9 cm (subject 1), 2.0 cm (subject 2), and 2.2 cm (subject 3). The VI displaced 21-47% less than the RF when the investigator moved the limb.

DISCUSSION

The results of our study indicate that the rectus femoris slides relative to the vastus intermedius. Therefore, we believe that the fascia between the muscles allows the relative motion of these muscles in unimpaired subjects. The displacements of the regions of interest within the rectus femoris were greater than the displacements of the regions of interest within the vastus intermedius; this is consistent with the observation that the rectus femoris has a larger moment arm (Buford et al., 1997).

This study demonstrates that we can quantitatively assess the relative motions of muscles *in vivo* using dynamic MR imaging. In the future we will use cine-PC MRI to measure the relative displacements of the rectus femoris and vastus intermedius in subjects with cerebral palsy after rectus femoris transfer surgery. If the rectus femoris is functioning as a knee flexor after transfer, it will move in the opposite direction of the vastus intermedius. We plan to quantify rectus femoris displacement to determine if scarring of the fascial plane restricts relative motion of the rectus femoris and vastus intermedius. This work will evaluate how adhesive scar tissue affects the function of rectus femoris after surgery.

REFERENCES

Buford, WL et al. (1997). *IEEE Trans Rehab Med*, **5**, 367-79.
Pappas, GP (2001). Ph.D. Dissertation, Stanford University.
Pelc, NJ et al. (1991). *Mag Res Quarterly*, **7**, 227-54.
Perry, J (1987). *Dev Med Child Neurol*, **29**, 153-8.
Riewald, SR, Delp, SL (1997). *Dev Med Child Neurol*, **39**, 99-105.
Zhu, Y et al. (1996). *Magn Res Med*, **35**, 471-80.

ACKNOWLEDGEMENTS

We are thankful to George Pappas, John Drace, and Doug Schwandt. Funding provided by NIH Grant HD38962 and Graduate Fellowships from the Whitaker Foundation and the NSF.