LOCAL BEHAVIORS OF FASCICLES IN HUMAN SKELETAL MUSCLES *IN VIVO* DURING DYNAMIC MOVEMENTS

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INTRODUCTION

Local force in muscle fascicles is a function of local fascicle behaviors such as changes in their partial length (length-force relation [1]) and velocity (velocity-force relation [2]). Also, the mechanical interaction between muscle fascicles and tendinous tissues is an important factor to determine fascicle behaviors in muscle contractions [3]. Recently, the Phase Contrast (PC) MRI study has revealed that under muscle contractile conditions, the distribution of strain along muscle aponeuroses is heterogeneous in the muscle [4]. However, it remains unknown how such heterogeneity of aponeuroses behaviors in muscle are linked to the local fascicle behaviors determining distribution and orientation of forces in the muscle-tendon complex. To address this issue, using PC MRI with mapping and two-dimensional (2D) analyses, the present study examined the local velocity and displacement of muscle fascicles in the medial gastrocnemius (MG) and soleus (SOL) muscles during dynamic movements.

METHODS

Subjects (presently 6 males) performed -64 dynamic dorsi and plantar flexions without external load in MR gantry at a rate of 60 cycles/min under the range from 20 to 30 degrees of planter flexion. During dynamic dorsi and plantar flexions, force was recorded with optical strain gauge attached to the foot plate, and used for the gating trigger to control MR imaging timing.

To measure velocity of tissue movement, an oblique sagittal PC MR image was acquired by 1.5T machine with a two-dimensional gradient echo PC sequence [16.6 ms repetition time, 5.9 ms echo time, 160 × 320 mm field of view, 128 × 256 matrix size, 5 mm slice thickness, 2 views/segment, 1 average, velocity encoding 7 cm/s, temporal resolution 63 ms, scan time 1:30] via a head coil. The slice location was carefully prescribed to include fascicles from end to end in the imaging plane. A total of 15 phases were acquired in each cycle.

From the velocities of anterior-posterior and superior-inferior directions measured by PC MRI, the 2D (in imaging plane) resultant vectors were calculated from all matrixes to determine local velocity. Also, using the velocity data, displacements of interest points (e.g. near points of muscle tendon junction and distal SOL) were determined to track the tissue movement two-dimensionally using in-house image analysis algorithms based on similar technique of the previous study [4]. The velocity of the tracked points was analyzed as well.

RESULTS AND DISCUSSION

Figure 1 demonstrates the typical example of the time course of amplitude of resultant velocity in tissues. The velocity mapping showed that high contraction velocity over 20 mm/s (red in Figure 1) was concentrated under the distal part of SOL and under the origin and insertion part of MG fascicles. The distribution of the velocity in muscle tissues of MG and SOL changed throughout all range of the dynamic dorsi and plantar flexions. The 2D analysis showed that the displacement and velocity of tracked points were heterogeneous in synergist muscles and even along anatomical fascicle direction in single muscle. This further suggests, according to the length-tension and force-velocity relations, the existence of different force generation profiles of each local point of fascicles during the movements.

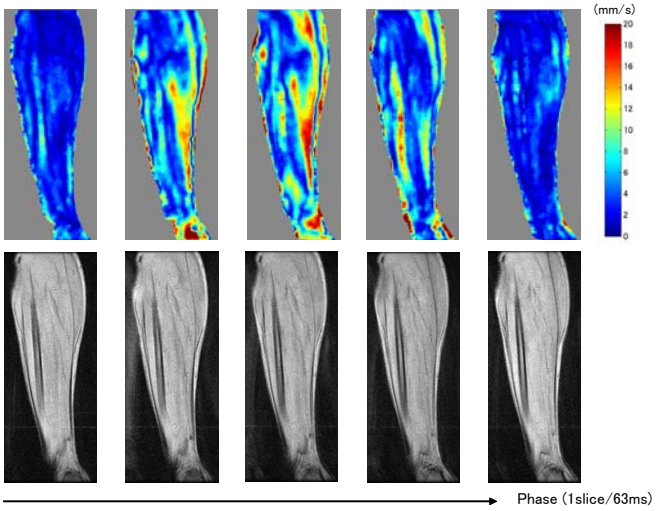

Figure 1: A typical example of resultant velocity mapping during planter flexion phase (uppers) and the corresponding anatomical images (bottoms).

CONCLUSIONS

The present study successfully showed the local behaviors (velocity and displacement) of muscle fascicles during dynamic movements in details. Throughout all range of the dynamic dorsi and plantar flexions, the displacement and velocity were heterogeneous in synergist muscles and even along anatomical fascicle direction in single muscle.

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