Measurement of Musculoskeletal Kinematics in Real Time using Ultrasound Imaging

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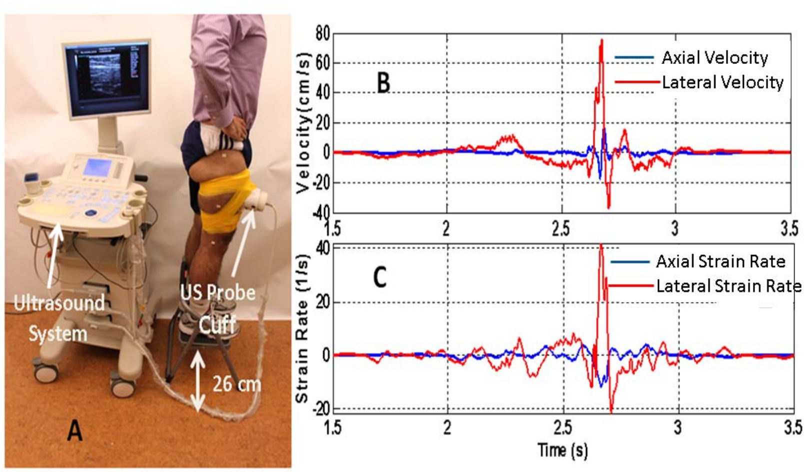
Introduction: Osteoarthritis (OA), a specific condition of arthritis, has a detrimental impact on activities of daily living and active lifestyles that can lead to direct and indirect health problems with health care costs of $98 billion annually. One of the prime causes of OA in young people is ACL tear and reconstruction. Up to 90% of the patients with ACL reconstruction present early symptoms of OA. Quantitative measurements of musculoskeletal kinematics, strain rate and strain can help in understanding the contributing factors that lead to early onset of OA. Real time ultrasound imaging can provide novel quantitative measures of musculoskeletal kinematics during a dynamic task. We have previously developed a vector tissue Doppler imaging (vTDI) method that can be used to measure musculoskeletal kinematics in real time. The goal of this study is to better understand the *rectus femoris* muscle kinematics, strain rate and strain during a drop jump task in healthy volunteers.

Materials and Methods: Eight (N = 8) healthy volunteers (4 men and 4 women; age = 29.7 ± 6.5 years) were recruited and provided informed consent approved by the Institutional Review Board. The exclusion criteria were previous diagnosis of neuromuscular disease, knee pathology or previous knee surgery. All subjects were asked to perform a natural drop jump from a platform at a height of 26 cm with their hands on their hips and land simultaneously on both legs, while ultrasound data were being collected using a Ultrasonix Sonix RP US system (Richmond, BC, Canada) with a 5-14 MHz linear array transducer as seen in Fig. 1a. vTDI was used to estimate velocity components based on measurements taken from two independent directions by electronically splitting the array transducer into two transmit and two receive apertures. Lateral (along the fibers) and axial (across the fibers) strain rate were calculated using the spatial gradients in the lateral and axial velocities and, strain was calculated by integrating the strain rate.

Results and Discussion: Axial and lateral muscle velocities were collected for all 8 subjects and compared to the strain development of the *rectus femoris* muscle during drop jump. Figure 1b shows the lateral and axial velocities obtained using vTDI during each jump sequence. The magnitude of the resultant velocity vector was obtained using the lateral and axial velocity components, which demonstrated high repeatability between trials ($ICC_{2,1}$ = 0.907, $p<0.05$). The lateral *rectus femoris* muscle velocity was predominant in the axial muscle velocities during the knee flexion and extension phase and high just after landing. Also, the *rectus femoris* lateral strain rate was between ±10 (1/s) during the flexion and extension phase for take off and was higher than axial strain rate. Strain rate occurred primarily in the lateral direction just after landing on the ground was about 40 (1/s) and in the axial direction was about -10 (1/s). In this scenario positive strain rate implies contraction and negative strain implies expansion. Also, the lateral strain during the trial is higher than the axial strain, the lateral strain reaching a maximum of 72% just after the jump.



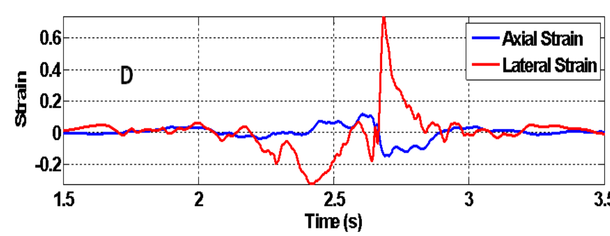


Figure1: Panel a. shows the experimental setup for the drop jump with the ultrasound probe held using a custom made probe holder and lexen bandage. Panel b. shows the axial and lateral *rectus femoris* muscle velocities. Panel c. represents the axial and lateral strain rate for the muscle during the entire sequence of the jump. Panel d. represents the axial and lateral strain development of the *rectus femoris* muscle during each trial.

Conclusions: Our preliminary results demonstrate that vTDI can be used in real time to measure musculoskeletal kinematics along with strain and strain rate. We are also in the process of integrating EMG and 3D motion capture systems with vTDI in our future experiments. Combining vTDI with the existing joint kinematic and kinetic measures will help provide information in better understanding OA post ACL reconstruction.

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