Purpose: Imaging the knee under realistic load-bearing conditions can be carried out in a horizontal plane using a C-arm CT scanner. Human subjects can be scanned in a standing position and acquired data successfully reconstructed. However, reconstructing this data is a challenge due to significant artifacts that are induced due to involuntary motion. Here, we propose motion correction methods in 2D and 3D.

Methods: Four volunteers were scanned for 8 seconds while squatting with ~30 degree flexion. Eight tantalum fiducial markers suitably attached around the knee were used to track motion. The marker position in each projection was semi-automatically detected. Each marker's static 3D position, which served as a reference to correct temporal motion, was estimated by triangulating each marker's 2D position from 248 projections using known projection matrices. Motion was corrected in 3 ways: 1) 2D projection shifting based on the mean position of markers, 2) 2D projection warping using approximate thin-plate splines, 3) 3D rigid body warping.

Results: The original reconstruction was severely motion-corrupted which made it impossible to distinguish the boundaries of bones. Reconstruction with projection shifting and warping in 2D improved visualization of edges of soft tissue as well as bone. A simple numerical metric of residual bead deviation from static position was reduced from 3.2mm to 0.4mm. The 2D-based methods are inherently limited in that they cannot fully accommodate different 3D movements at different depths from the X-ray source. Reconstruction with 3D warping shows clearer edges and less streak artifact than the 2D methods.

Conclusions: The proposed three motion correction methods effectively reduced motion-induced artifacts in the reconstruction and are therefore suitable for weight-bearing scanning. Future work includes scanning patients in standing position after contrast injection for evaluating the soft tissue structure and constructing 3D finite element models for the estimation of joint cartilage stress.