INTRODUCTION
Robots, particularly parallel robots, have great potential to further the field of biomechanics with their accuracy, precision, load capacity and full six degree of freedom (6DOF) mobility. The flexibility and hybrid protocols are essential for the biomechanical evaluation of joints and their repair. Velocity-based control uses feedback from the 6DOF load cell to set a velocity on each axis proportional to the error between the desired force and the actual measured force. Previous methods have set a low maximum velocity threshold to ensure stability and avoid approximation of a specimen stiffness [1]. An improved velocity-based control method has been developed which aims to enable dynamic, physiologic, unconstrained 6DOF force control in a hexapod robot [2].

METHODS
Our method builds on previous work [1] by introducing a six-axis adaptive gain which at 100Hz adjusts the velocity based on the specimen stiffness and force feedback tracking over the last second. In this way the actual specimen stiffness need not be known and further feedback analysis (RMS error, weighted average, oscillation frequency) balances system stability with velocity to achieve optimum performance. Tracking overshoot and sensitivity to noise was overcome by relating force error to velocity with a hyperbolic sin function. A force command-based feedforward control loop was added to increase the tracking performance in dynamic loading.

An ovine lumbar functional spinal unit, hydrated in a 37°C protease inhibitor PBS bath was tested to validate the method for biomechanical testing. A follower preload simulating a typical 0.2MPa intradiscal pressure was applied normal to the disc midline.

The large neutral zone was accounted for by allowing the constraint of the bending axes to a target rotation via position control. This constraint provided a repeatable reference point from which to begin each test. Constraining rotation about the coupling moment axis allowed for the force controlled, 5DOF application of shear.

Waveforms applied were 8Nm in flexion, extension, lateral bending and axial rotation, 100N anterior/posterior and lateral shear and 300N compression at 0.01Hz up to 0.3Hz.

RESULTS AND DISCUSSION
Mean RMS (SD) errors across all 0.01Hz tests for translation axes were 5.13 (0.91) N and 0.344 (0.25) Nm for rotations and were restricted to the noise floor of the signal (±6N,±0.4Nm). Reasonable tracking was achieved up to 0.3Hz.

CONCLUSIONS
This improved velocity-based force control method is capable of flexibility testing any joint, tissue, implant or intervention in complete 6DOF at frequencies up to 0.3Hz.

REFERENCES
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