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Insights into kinematics of the knee joint using ground reaction control in the UGent knee rig

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Abstract

Introduction

In-vitro cadaver tests in dynamic knee rigs are used to investigate the feasibility of knee implants and surgical techniques [1]. In combination with infra-red cameras, kinematics of the knee joint can be tracked during applied movements. Orthopedic researchers wish to compare kinematic data sets in pre- and postoperative cadaver specimens in order to validate implant design and surgical techniques. The UGent Knee Rig (UGKR) has an increased flexibility compared to traditional rigs as it is capable of performing any type of motion while applying quadriceps and hamstring forces [2]. In-vivo tests on knee implants include gait lab measurements where the ground reaction forces (GRF) are measured. Providing a control structure in the UGKR to apply different GRF is the current scope.

Methods

The UGKR consists of five different actuators applying the desired ankle position in the sagittal plane and muscle forces (Figure). A sensor at the ankle joint measures the GRF during the motion. In order to provide reliable kinematic data sets which can be statistically compared, a decoupled control structure is implemented to maintain fixed loading conditions on the GRF. Based on the difference between the desired GRF and the measured GRF, the controller adjusts the quadriceps and hamstring forces using the mathematical relationships. A cadaver specimen is inserted into the UGKR and undergoes a squat movement where the knee starts in deep flexion (flexion angle of 120°) and goes to extension (flexion angle of 20°). During this motion either the vertical component of the GRF is kept constant or the horizontal component is changed parabolically by adjusting the applied quadriceps force (Figure).
Results and Discussion

Two squat motions with periods of 30 s have been performed on the UGKR: i) keeping a constant vertical component of the GRF and ii) changing the horizontal component of the GRF parabolically. The references and measured components of the GRF are plotted in Fig. 1 for both measurements. Note here that the maximal error on the GRF is less than 3 N which is 10% of the desired value. This error is acceptable to obtain comparable kinematic data sets.

Conclusion

This research presents a control strategy to maintain desired GRF during motions in the UGKR. Validation of the control strategy is done on cadaver specimens. The results show good reference following on each component of the GRF with acceptable errors to obtain statistically comparable kinematic data sets for orthopedic research.

References