INTRAARTICULAR FORCE DISTRIBUTION IN THE FEMOROTIBIAL JOINT IS RELATED TO KNEE ADDUCTION MOMENT AND KNEE FLEXION

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INTRODUCTION AND PURPOSE

Varus malalignment of the knee has been identified as a risk factor for the development and progression of knee osteoarthritis (Brouwer, 2007). Varus malalignment is associated with an increased external adduction moment at the knee during ambulation and the determination of the external adduction moment at the knee is commonly used to predict the biomechanical risk of osteoarthritis (Andriacchi, 1994). It has been speculated that the external adduction moment alters the load distribution between the medial and lateral compartment of the knee. Fantini Pagani et al. (2010) demonstrated that a valgus bracing can modify the resulting net moment of the knee in the frontal plane during daily activities such as walking by applying an external abduction moment. Furthermore the redistribution of the load between the medial and lateral compartments as a result of an external valgus moment to the knee by a valgus knee brace was reported by applying a simple mathematical model (Shelburne et al., 2008). Kutzner et al. (2011) measured a decreased medial compartment forces when applying an external abduction moment by an orthosis measured with an instrumented implant during walking in three patients. The published adduction moments during the gait cycle indicate a possible relationship of the resultant adduction moments and the knee flexion angle and therefore a relation of knee medial compartment loading and knee flexion. No experimental data of pressure distribution within the knee joint compartments of a native joint as a function of the knee adduction moment and knee flexion angle are available.

The purpose of the study is to quantify the intraarticular force distribution in the femorotibial joint in relation to the external adduction moment and the knee flexion angle.

MATERIALS AND METHODS

A dynamic muscle controlled knee squat was simulated on six fresh-frozen human leg specimens with an upright knee simulator. During knee flexion and extension the femorotibial pressure distribution was measured with two Kneepad S sensors (Novel, Munich). Experimentally an external adduction/abduction moment was applied by a customized orthosis which allowed the application of moments from -5 to 5 Nm. The specimens were amputated at 250 mm from the knee joint line, the femur was mounted onto a steel cylinder and positioned in the simulator. The extensor muscles and the hamstrings were connected with pneumatics actuators which applied a constant force of up to 100 N in order to counterbalance gravitational forces to the muscles. The patella tendon was enforced by a 15 mm wide polyester band, which was screwed to the patella and proximally connected with a pneumatic actuator (250, 500, 750 N). Additional axial forces of 100 and 250 N were applied to the femur. The motion of the femur and the tibia was measured by a six-camera 3D motion analysis system (Vicon Nexus) operating at 100 fps (bone pins in femur and tibia with retro reflective marker arrays).

RESULTS

The range of knee flexion during the simulated squat was measured at 60 ± 5° indicating that the simulation covers the range of knee flexion during daily activities. Medial compartment force was higher than the lateral compartment force for all specimens with neutral or varus knee alignment. With increasing knee flexion the medial compartment force increases. The externally applied moment is strongly related to the relative and absolute medial compartment loading.

DISCUSSION

Medial compartment joint load is a function of the external adduction moment and knee flexion. With externally applied abduction moments, e.g. by valgus braces, the remaining adduction moment at the knee and therefore the medial compartment load can be reduced. This result and the relationship between medial compartment load and knee flexion offers novel concepts for the development and optimization of technical aids and conservative treatment of the osteoarthritic knee. The findings have relevance for the adjustment of mechanical aids to reduce the intraarticular knee loading at a minimum of patients' compliance.

REFERENCES

Andriacchi, Orthop Clin N Am 25, 395-403, 1994.
Brouwer et al., Arthritis Rheum 56, 1204-1211, 2007.
Fantini Pagani, et al., Clin. Biomech 25, 70-76, 2010.
Kutzner et al., J.Biomech 44, 1354-1360, 2011.
Shelburne et al., *Clin. Biomech* 23, 814-821, 2008.