Patellofemoral contact areas during simulated weight bearing squat

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Introduction
Squatting is a highly demanding exercise commonly used in sports and rehabilitation programs to strengthen the quadriceps. In this study cadaveric knees were mounted in the Ghent test rig to simulate a weight bearing squat. During this dynamic flexion-extension movement, the patellofemoral contact area’s and pressures are continuously monitored.

Materials and methods
Embalmed knees were mounted in the test rig after they were considered intact and without any morphological abnormalities, based on CT scans. A Tekscan pressure sensitive sensor was inserted in the patellofemoral joint through a lateral release to measure the contact pressures and contact area of the patellofemoral joint. In addition, the Tekscan pressure film also provides a good visualization of the location of contact on the patella. The tests were performed with a linear motor speed of 2mm/s and a knee angle range from 175° (almost full extension) to 135° (45° flexion). During this squat simulation the knees are loaded with a weight of 30 kg which equalizes a normal weight on 1 leg during bipedal stance (mass above hip height/2).

Results and discussion
Starting with a flexed knee, the tension in the quadriceps tendon is first built up by the linear actuator; in this phase no movement is observed (static extension phase). As the tension increases, the quadriceps force and patellofemoral contact area and pressure increase simultaneously (see fig. 1). When the quadriceps force reaches a maximum of almost 2750N, the knee starts to extend. During this dynamic knee extension phase, all measured parameters decrease again until full extension. At that point, the linear actuator has to change direction to allow the knee to bend. As the linear actuator offers resistance against the gravity, all parameters increase again until the deepest knee bending is reached (at a max. quadriceps force of 1630N). While the knee stays in this bended position all parameters decrease again. For a knee angle range of 135°-175°, the variance in patellofemoral contact area is almost completely explained by the knee angle (see fig 2).

Fig. 2: Patellofemoral contact area in relation to the knee angle with pressure distribution at 135 and 175° knee angle

Closer examination of the patellofemoral contact area reveals that it is 8% lower during the dynamic flexion phase compared to the dynamic extension phase, which can easily be explained by the higher quadriceps forces during the extension (max. 2750N) compared to the flexion movement (max. 1630N). These high quadriceps forces, characteristic for a weight bearing condition, are also responsible for the fact that the contact areas measured in this study are approximately 20% larger than those reported in previous unloaded studies. Larger dynamic loadings seem to improve the joint congruity compared to static unloaded test conditions.

Conclusion
Patellofemoral contact pressures and areas should be measured under weight bearing dynamic conditions to account for the patellar position in the trochlear groove and the patellofemoral congruity. Further research should be done to understand the complex interaction between cartilage contact area, joint contact forces, and resulting cartilage stresses in the patellofemoral joint during weight bearing squat.

References