INTRODUCTION:
Implant alignment has been identified as a significant risk factor for impingement and dislocation in total hip replacement, with alignment of the acetabular cup being a crucial component. Many surgeons aim to align the cup at 40°±10° of inclination and 15°±10° of anteverision, based on the “safe zone” proposed by Lewinnek, et al. These recommendations assume a neutral pelvic tilt angle of the patient, which is difficult to determine during conventional surgery. Computer navigation techniques, based on the anterior pelvic plane, may also need to take into account the pelvic tilt. This brings into question the previously accepted range of optimal cup alignment: Should it vary as a function of pelvic tilt? The objective of this study is to investigate the effect of pelvic tilt on hip range of motion (ROM) given a standard cup alignment. ROM is investigated during standing and during three activities of daily living that are prone to dislocation.

METHODS:
Range of motion was assessed using a hip ROM simulator developed in-house. The simulator computes and animates hip range of motion as a function of implant geometry, implant alignment, and patient activity. The user is provided a three-dimensional model of the skeletal system that contains anatomic coordinate systems for the pelvis and femur. For the pelvis, the coordinate system is developed based on the right and left ASIS and the pubic symphysis. The orientation of this coordinate system can be modified by specifying a pelvic tilt parameter, defined as the angle between a plane containing both ASIS and the pubic symphysis (the anterior pelvic plane) and a global vertical plane. CAD models of hip implants can be imported into the model and positioned in any desired orientation about the anatomic coordinate systems. The software can then compute minimum clearances between the components for any hip position, report total hip ROM in flexion/extension, ab/adduction, and internal/external rotation during standing, and compute the remaining ROM of the joint at regular intervals during eight functional activities. Motion data for the eight activities were obtained from gait analyses performed on ten healthy subjects. The software reports ROM as the amount of motion attainable before component - component impingement occurs.

For the present study, range of motion was assessed on a standard stem with a 132° neck angle and a 36 mm head articulating with a 36 mm liner in a 54 mm acetabular shell (Stryker Orthopaedics, Mahwah, NJ). Inclination of the cup was set to 45° and anteversion to 20°. Pelvic tilt was varied from -10° (posterior pelvic tilt) to 30° (anterior pelvic tilt), in increments of 5°. For each pelvic tilt angle, the total ROM was computed in flexion/extension, ab/adduction, and int/external rotation at 0° and 90° flexion. At -10°, 0° and 30° of tilt, ROM limits were also computed during three activities: A low chair rise, a squat, and picking up an object.

RESULTS:
Figure 1 displays ROM of the hip as a function of pelvic tilt during standing. Graphs are shown for flexion/extension, ab/adduction, and int/external rotation at 0° and 90° flexion. In flexion/extension, the total ROM remained constant over increasing pelvic tilt angles, however the flexion end limits decreased while the extension end limits increased. Total ab/adduction ROM increased with pelvic tilt, along with the abduction and adduction end limits. Total int/external ROM increased, however the internal end limits decreased while the external limits increased. With the hip flexed to 90°, the opposite effect on int/external ROM is seen. Total ROM, along with both end limits, decreased substantially with pelvic tilt.

Figure 2 displays graphs of the hip excursion angles in each plane during one cycle of a low chair rise activity, assuming a pelvic tilt of -10°, 0° and 30°. The black line in each graph represents the average hip excursion angle, while the red lines above and below it represent the limits of motion in that plane before impingement would occur. The results show that at -10° and 0° tilt, no impingement occurs between the components throughout the activity. At 30° of tilt, however, the black line crosses over the red lines in all planes between 25% and 50% of the motion cycle, indicating that impingement has occurred. Similar results were seen for picking up an object, with impingement occurring between 40% and 55% of the cycle at 30° tilt. No impingement was seen for any tilt angle during a squatting activity.

DISCUSSION:
The results of this study demonstrate that a patient’s pelvic tilt can have a substantial effect on the attainable ROM of the hip. Assuming a generally accepted cup alignment of 45° inclination/20° anteversion, increasing amounts of pelvic tilt can limit flexion and int/external rotation, and lead to impingement during functional activities. This finding supports the work of Babisch, et al., who suggest that the optimal range of cup alignments needs to be modified when orienting the cup in the anterior pelvic plane.

REFERENCES: