INTRODUCTION:

Previous in vivo studies pertaining to total hip arthroplasty (THA) performance have focused on the analysis of gait; unfortunately, higher demand activities have not yet been analyzed. In vitro methods have been developed to test the long-term endurance of implants, taking into account a variety of activities of daily living – while these studies are valuable for preclinical evaluations, they do not analyze the performance of implants in a true in vivo environment. Dynamic, weight-bearing in vivo studies have shown that femoral head sliding does occur in THA subjects.\(^1\) A possible concern is that the consequent impact following separation leads to increased loading conditions at the bearing surface interface, especially superolaterally, which may lead to increased wear at the implants’ bearing surfaces. Therefore, the objective of the present study was to determine the in vivo kinematics and separation values for THA patients, using fluoroscopy, while they performed four higher demand activities and evaluate if separation incidence and magnitude varies among the different activities.

METHODS:

The 3D in vivo kinematics of 10 THA patients were analyzed during the following activities: pivoting, tying a shoe, sitting down, and standing up. Patients were matched for age, height, weight, body mass index, diagnosis, and femoral head diameter to control for confounding variables possibly having influence on the hip performance and kinematics. Patients were judged clinically successful (Harris Hip Score HHS>90). Institutional Review Board (IRB) approval was obtained and each subject signed an informed consent form before being allowed to participate in the study. While performing an activity under fluoroscopic surveillance, multiple images were captured at appropriate intervals and subsequently analyzed using MATLAB\textsuperscript{TM} applications alongside a three-dimensional model fitting process. The result of these processes was a highly accurate view of the orientation of the femoral and acetabular components of the implanted device, which was used to diagnose if separation has occurred. A student’s t-test with a risk level of 0.05 was used to test for significance between the group means and incidences of separation.

RESULTS:

Average separation values differed across the four activity groups (Figure 1). The highest average hip separation was observed during the pivot activity with 1.5 mm (0.0 – 3.3 mm, SD 1.05 mm). Lowest separation values occurred while performing the stand-up activity, with an average of 0.7 mm (0.0 – 1.6 mm, SD 0.46 mm). A comparison between the pivot and stand-up datasets showed statistical significance ($P = 0.02$), while all other comparisons were insignificant.

![Figure 1: Average Separation Values Across Activities](image)

Using a threshold of separation significance of 0.5 mm, 9 of 10 (90%) patients exhibited significant separation in the pivot and sit-down exercises, while only 6 / 10 (60%) of the stand-up group presented separation. High hip separation incidence persisted during pivot when analyzing separation at a threshold of 1.0mm (60%); considerably less incidence was found in shoe tie and sit-down and was nearly absent in stand-up (Figure 2).

![Figure 2: Incidence of Separation (> 1.0 mm)](image)

Distinct trends were observed for each activity by relating calculated separation values to the progression of the executed motion. In analysis of the pivot activity, maximal separation occurred during internal rotation of the hip in 80% of patients – higher separation values were consistently found in the most extreme rotations, while little or no separation occurred in the neutral position. All ten subjects presented greatest separation in the latter half of the shoe tie activity, when the upper body is most bent forward. The sit-down exercise showed a trend of decreasing separation values through the activity, while the stand-up exercise demonstrated an opposite trend of an increase in separation.

DISCUSSION:

Previous studies have reported separation occurrence in both gait and abduction/adduction activities. This study demonstrates that separation occurs in other commonly encountered daily activities. Each activity analyzed presented high incidence and magnitude of separation. In observed cases of separation between the femoral head and acetabular cup, contact area between the two components is reduced. A separation of the medial surfaces leads to a much smaller superolateral region of contact; therefore, the femoral head often pivots on the peripheral rim of the liner when separation values are extreme. These abnormal operations and lessened contact areas may cause higher exerted pressures on the articular surfaces, potentially leading to increased wear of the components. In comparison with past studies, our findings during the pivot activity exceed the common separations encountered in walking. An average separation during pivot of 1.5 mm was higher than the previously reported 1.2 mm encountered during gait. The other activities within the study presented lower magnitudes and incidences of separation than previous gait studies. From these results, we can conclude that examination of the pivot activity alongside gait is important when focusing on the extremes of hip joint activity during daily usage. Also, an in-depth, detailed analysis of a pivot-type motion would be highly beneficial in determining the separations encountered by healthy subjects during an average day, and therefore would be a useful tool to be considered during the design phase of hip implant development. Levels of separation encountered in this study were approaching values found to be excessive in clinically successful hip implants while performing gait.\(^2\) One can infer, then, that separations encountered during these activities in malfunctioning or unhealthy implantations may be quite detrimental. Further studies may be needed to explore the upper boundaries of separation values in hip arthroplasty.
