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The effect of surgical approach on gait mechanics after total hip arthroplasty

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A R T I C L E I N F O

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A B S T R A C T

Background: Few studies have compared the biomechanical outcomes of different surgical approaches for hip arthroplasty. The purpose of this study was to compare hip, pelvic, and trunk kinematics and kinetics between individuals who underwent a posterior or anterolateral approach.
Methods: Forty-five individuals between 40 and 80 years old underwent motion analysis during overground gait prior to hip arthroplasty and 3 months after surgery. Walking speed, hip flexion angle, hip extension angle, adduction angle and moment, trunk angle, trunk lean, and pelvis drop were compared between approaches.
Findings: There were 30 subjects in the posterior group and 15 subjects in the anterolateral group. The groups did not change differently over time as there were no significant interaction effects. However, there were main effects for time; walking speed increased 19.9% ($p < .001$), hip flexion angle increased 3.3 degrees ($p = 0.014$) and peak hip extension increased 4.5 degrees ($p = .001$), and peak hip adduction significantly increased 1.9 degrees ($p = .004$) for the sample as a whole. Trunk angle ($p = .283$) and trunk lean ($p = .401$) did not significantly change between time points, but there was a significant increase in pelvic drop ($p = .003$).
Interpretation: Surgical approach did not affect biomechanical outcomes 3 months after arthroplasty. Both groups showed improvement in sagittal plane hip kinetics and kinematics. However, increased pelvic drop may be indicative of residual hip weakness in both groups.

1. Introduction

Total hip arthroplasty (THA) successfully relieves pain and improves function for the majority of individuals with osteoarthritis of the femoroacetabular joint (Learmonth et al., 2007; Vissers et al., 2011). Currently, there are multiple approaches to access the hip joint for this surgery, the most common of which are the anterior (Smith-Petersen) (Post et al., 2014), anterolateral (Watson-Jones, Modified Hardinge) (Jones, 1934), lateral (Hardinge, Transgluteal) (Foster and Hunter, 1987; Hardinge, 1982) and posterior (Moore, Southern, Posterolateral) (Gibson, 1950; Weaver, 1975) approaches. Worldwide, the posterior approaches are most common (45%), although the lateral approaches (42%) are a close second (Chechik et al., 2013). The safest and most clinically effective surgical approach is an ongoing topic of dispute in the field of orthopedics. Current recommendations state that surgeons should perform the approach with which they are most experienced (Petis et al., 2015) and should tailor their approach to the requirements of the case (Ninomiya et al., 2015).

In the posterior approach, the femoral head is exposed through blunt separation and retraction of the gluteus maximus and tenotomization of piriformis and the deep external rotators of the hip where they insert onto the greater trochanter. At the end of the operation, the external rotators and capsule are repaired. Since the gluteus maximus is primarily involved in hip extension and the external rotators significantly contribute to joint stability, there is the potential for hip extension weakness and joint instability with this approach (Masonis and Bourne, 2002; Sheth et al., 2015). However, the advantage of this approach is that the hip abductors, principally gluteus medius and minimus, are spared during the process of femoral and acetabular exposure (Hoppenfeld et al., 2012). In contrast, the anterolateral approach requires posterior retraction or transection of the gluteus medius and/or transection of the gluteus minimus in order to expose

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the femoral head (Foster and Hunter, 1987; Mulliken et al., 1998). Release and retraction of the origin of the vastus lateralis from the anteroinferior trochanteric region may also be necessary to expose the joint capsule, although these structures are usually repaired prior to closing. Lateral approaches that affect the hip abductor muscles may be associated with greater postoperative deficits in frontal plane trunk, pelvis and hip stability (Krautwurst et al., 2013). Previous clinical assessments of frontal plane pelvis stability revealed that patients who underwent an approach that affected the abductor muscles were more likely to present with pelvic drop, as defined by a positive Trendelenburg test (Baker and Bitounis, 1989). Other outcome studies have revealed that both approaches result in similar improvements in strength, gait, and pelvis stability (Barber et al., 1996). However, these studies have only compared clinical measures of trunk lean and pelvic drop during static standing positions, which may not objectively reflect pelvic stability during dynamic weight bearing motions like gait.

While several large studies have compared functional and clinical outcomes between approaches (Berstock et al., 2015; Higgins et al., 2015), few studies have evaluated outcomes using objective three-dimensional motion analysis. Therefore, the purpose of this paper was to evaluate differences in sagittal and frontal plane kinematics and kinetics between patients who underwent THA using either a posterior or anterolateral approach. We hypothesized that patients in the anterolateral approach group would have greater trunk lean, pelvic drop and lower external hip adduction moments on the affected side 3 months after surgery, but there would be no differences in the sagittal plane between groups. In the event of no group differences, a secondary aim of this study was to evaluate whether there were changes over time for the sample as a whole. We evaluated movements in the frontal and sagittal planes as abnormalities in these planes are commonly observed and treated for patients with hip pain, weakness, and instability.

2. Methods

2.1. Subjects

Individuals between 40 and 80 years of age scheduled for primary total hip arthroplasty for end-stage osteoarthritis were recruited by mail and advertisements placed in the physicians' offices. Subjects were only included if they were undergoing a primary THA for osteoarthritis and were excluded if undergoing a revision or THA for fracture or rheumatoid arthritis. Subjects were also excluded if they had neurological or cardiopulmonary conditions that interfered with their ability to move or walk the equivalent of several city blocks, required an assistive device for safe ambulation, had active cancer, or had lack of sensation in their feet. For this project, subjects were excluded from the analysis if they were undergoing simultaneous or staged bilateral THA or had undergone a previous joint replacement. Subjects participated in two testing sessions. Baseline testing took place 2 to 4 weeks prior to surgery and follow-up testing occurred 3 months after surgery. This follow-up period coincides with the time at which most patients are cleared to return to higher level activity and strengthening exercises. This is an important timepoint to evaluate frontal plane compensations as underlying strength deficits can be addressed through targeted strengthening programs 3 months after surgery.

All subjects underwent surgery at the Delaware Center for Joint Replacement with a volume of approximately 800 THA procedures per year. For the purposes of this paper, we included all subjects who were enrolled in the parent observational study and underwent a posterior or anterolateral (Modified Hardinge) approach (Fig. 1). This included patients from four surgeons. Two surgeons performed the posterior approach (n = 30) and 2 surgeons performed the anterolateral approach (n = 15). All subjects signed an informed consent form and this project was approved by the Human Subject Review Board.

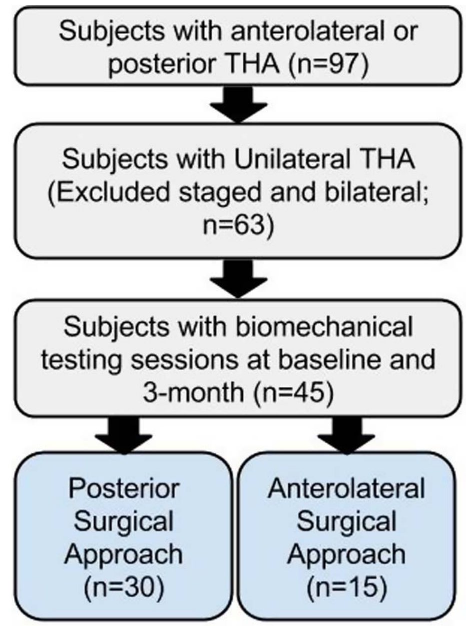

Fig. 1. CONSORT diagram demonstrating subject enrollment and exclusion.

2.2. Data collection

Subjects completed motion analysis of overground gait along a 10 m walkway at their self-selected speed. During the test, walking speed was measured using wireless timing gates (Brower Timing Systems, Draper, UT, USA). All subjects wore comfortable footwear during the test and were instructed not to wear sandals, heels or open-toed shoes. Overground gait was measured via an eight camera system (Vicon Motion Systems Ltd, Oxford, UK). Reflective markers were placed on anatomical landmarks and tracking shells were used to quantify segment motion as previously described (Zeni et al., 2014). Functional hip joint centers were determined from a dynamic calibration trial (Schwartz and Rozumalski, 2005). Lower extremity and trunk angles were calculated using Euler sequence for sagittal, frontal, and transverse rotations in that order. Ground reaction forces were obtained at 1080 Hz from two force plates (Bertec Corporation, Columbus, OH, USA) that were placed in tandem in the direction of walking. Each subject completed five successful walking trials, which were defined as a trial within 5% of self-selected speed and no intentional targeting of the force plate. Only the surgical limbs were analyzed for this study.

2.3. Data processing

Data were processed using Visual3D software (C-Motion Inc., Germantown, MD, USA) for kinematic and inverse dynamic analyses. Kinematic data were filtered at 6 Hz and kinetic data were filtered at 40 Hz using a second-order phase corrected Butterworth filter. Joint angles and moments were calculated during the stance phase of gait and time normalized to 100% of the stance phase of the gait cycle. Joint moments were also normalized to body mass (kg) and height (m), and reported as external moments.

2.4. Outcome variables

Outcome variables included self-selected walking speed, peak hip flexion angle, peak hip extension angle, peak adduction angle and moment, peak frontal trunk angle, peak lateral trunk lean, and pelvis drop. Peak hip flexion angles were derived from the first 50% of stance and peak hip extension from the last 50% of stance. Peak hip adduction angle and moment were also assessed over the entire stance phase. Frontal plane trunk movement was measured in two ways. First, peak