GAIT DOES NOT RETURN TO NORMAL FOLLOWING TOTAL HIP ARTHROPLASTY: IMPLICATIONS FOR A RETURN TO ATHLETIC ACTIVITIES

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The purpose of this study was to determine the effect of total hip arthroplasty (THA) on the biomechanics of the lower extremity during walking. Twenty THA patients and 20 healthy control participants performed several trials of level walking for which three-dimensional (3D) hip, knee and ankle angles, forces, moments and powers were recorded and calculated. Results revealed that the gait mechanics of THA patients do not return to normal following surgery, especially during the transition from double- to single-limb stance. These patients produced lower hip abduction moments that are perhaps a result of hip abductor weakness. Kinematic and kinetic adaptations at the distal joints were also found. Hip musculature deficiencies should be addressed in rehabilitation programs, especially if patients want to return to athletic activities.

KEY WORDS: total hip arthroplasty, hip abductors, gait, kinematics, kinetics.

INTRODUCTION: The characteristics of individuals undergoing total joint replacement have vastly changed over the past decades. Total hip arthroplasty (THA) patients are more physically active and live longer (Crowninshield et al., 2006), and thus, have higher expectations for the longevity and performance of their implant. Although pain relief continues to be one of the top-ranked expectations of THA candidates, the majority of these individuals also places great importance on their expectation for the surgery to improve their ability to exercise and play sports (Mancuso et al., 2003). The literature demonstrates that THA patients do indeed experience a remarkable relief in pain following surgery. They are not satisfied, however, with their ability to perform athletic activities and sports, such as swimming, tennis, golf and hiking, among others (Mancuso et al., 1997). Given that results from various studies show that one's gait does not return to normal following THA (Foucher et al., 2007; Vogt et al., 2004), this dissatisfaction may stem from a muscle weakness that is thought to be responsible for the abnormal gait patterns. Hence, muscle weakness may not only decrease THA patients' satisfaction of their athletic performance, but also increase their risk of injury during such activities and jeopardize the longevity of the implant. Although many researchers have performed gait analyses on THA patients post-operatively, most studies have ignored adjacent joints that are essential parts of the kinetic chain (e.g., knee and ankle joints) without performing a complete biomechanics analysis (Foucher et al., 2007; Vogt et al., 2004). And by completing such a thorough analysis, we might gain a better understanding of the cause(s) of these patients' deficiencies, which could be subsequently targeted during rehabilitation, and thus result in greater patient satisfaction during athletic activities. Consequently, the purpose of this study was to determine the effect of THA on mobility by comparing three-dimensional (3D) hip, knee and ankle joint angles, resultant inter-segmental joint forces and moments and powers during level walking of THA patients with those of healthy, matched control participants.

METHODS: Participants: Twenty THA patients (10 women, 10 men; age: 66.2 ± 6.7 yr; BMI: 27.2 ± 5 kg/m^2) and 20 healthy control participants, matched for gender, age and BMI (10 women, 10 men; age: 63.5 ± 4.4 yr; BMI: 24.9 ± 3.5 kg/m^2) were recruited on a voluntary basis. Exclusion criteria included bilateral hip replacement, hip replacement due to infection, fracture or failure of a previous prosthesis, concomitant surgical procedure during the surgery, as well as any past or present condition that could alter gait (e.g. stroke). Furthermore, all control participants had no current or history of serious lower limb injury or disease. All THA patients were operated by means of a lateral approach and were subsequently tested between 6 and 15 months postoperatively. Informed written consent, approved by the institutions' research ethics boards, was obtained from each participant.

Data Collection: A nine-camera digital optical motion capture system (Vicon MX, Oxford, UK) was used to capture, at 200 Hz, 45 retro-reflective markers (14 mm diameter) placed on various landmarks of the participants, according to a modified Helen Hayes marker set, while they executed the walking trials at a natural speed. Additionally, a force platform (AMTI, Model ORC-6-2000, Watertown, MA, USA) was used to record, at 1000 Hz, ground reaction forces during the stance phase of the gait cycle. Each participant performed six successful walking trials, three with their left foot and three with their right foot landing on the force platform. Walking trials during which the participant altered his/her gait to make contact with the force platform were discarded.

Data Analysis: The 3D marker trajectories were filtered using a Woltring filter (predicted Mean-Square Error value of 15 mm^2), whereas a low pass Butterworth filter (cut-off frequency of 6 Hz) was applied to the ground reaction forces. Following calculation of 3D hip, knee and ankle angles, the peak and range of these joint angles of the gait cycle were obtained. From the resultant inter-segmental joint forces and moments, as well as the joint powers, which were computed by means of the inverse dynamics approach, the peak joint kinetics during the stance phase of the cycle were extracted as variables of interest.

Statistics: Using SPSS statistical analysis software (SSPS for Windows, version 15.0, SPSS Inc., Chicago, USA), a series of one-way ANOVAs were executed to determine the presence of significant differences between the THA and control groups with regard to the 3D hip, knee and ankle kinematic and kinetic variables. Alpha levels of 0.0167 and 0.025 (corrected for multiple comparisons) were used to determine statistical significance of the kinematic and kinetic variables, respectively.

RESULTS: No significant differences between the THA and control groups were found with regard to age and BMI ($p > 0.05$). Results from one-way ANOVAs showed that a large portion of the statistically significant differences found between the experimental and control groups occurred at the time of transition from double- to single-limb stance (i.e., contralateral foot-off), as listed in Table 1. For this reason, as well as space limitation, only those variables will be presented and discussed, although several other significant differences were found between groups.

Table 1: Means (standard deviation) of the kinematic and kinetic variables found to be significantly different between THA patients and control participants during the transition from double- to single-limb stance of the gait cycle.

Type of variable	Joint	Variable	Value THA	Value Control	p-value
Angle (°)	Hip	Peak adduction	7.6 (2.5)	9.8 (2.2)	0.005
	Ankle	Peak external rotation	-10.5 (4.3)	-14.2 (3.9)	0.007
Joint Reaction Force (N/kg)	Hip	Peak anterior	-1.52 (0.81)	-2.31 (0.83)	0.004
	Knee	Peak proximal	9.27 (0.88)	10.04 (0.69)	0.004
	Ankle	Peak posterior	1.75 (0.43)	2.11 (0.32)	0.004
	Ankle	Peak proximal	9.64 (0.87)	10.37 (0.70)	0.006
Moment (Nm/kg)	Hip	Peak abduction	-0.76 (0.15)	-0.90 (0.11)	0.003
	Ankle	Peak internal rotation	0.09 (0.10)	0.03 (0.02)	0.010

DISCUSSION: It was found that the THA patients' gait mechanics during the task of walking on a level surface do not return to normal following surgery, especially during the transition from double- to single-limb stance. As most of the body weight shifted on the ipsilateral hip, the control participants produced a greater hip abduction moment of force while their hip was in a more adducted position in comparison with the THA patients (Figure 1).

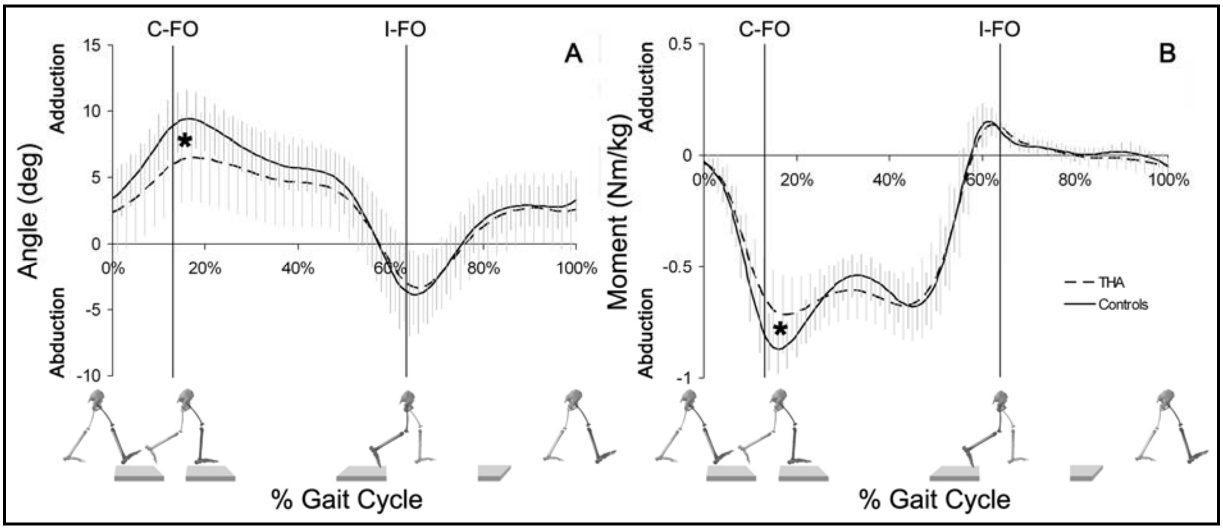

Figure 1: Average (and standard deviation represented by grey vertical lines) (A) hip angle and (B) hip moment of force in the frontal plane during level walking, time-normalized to the gait cycle. The asterisks (*) represent statistically significant differences between the THA and control groups.
C-FO = foot-off of contralateral limb; I-FO = foot-off of ipsilateral limb.

Similar findings have been previously reported in the literature (Foucher et al., 2007). It has been speculated that this altered gait pattern results from a weakness of the hip abductors. By adopting a mechanical strategy that places the hip in this less adducted position, THA patients require a smaller counteracting hip abduction moment of force to stabilize the pelvis in the frontal plane. Furthermore, several studies have demonstrated lower hip abductor strength in patients, both pre- and post-operatively, in comparison with control participants (Shih et al., 1994), although pre-surgery strength measurements may be questionable given that most THA candidates experience hip pain that can limit their ability to maximally contract their hip abductors. Several theories have been proposed as to the origin of this hip abductor weakness. Some researchers hypothesize that this weakness stems from disuse atrophy developed pre-operatively as a result of adopted gait patterns that limit contraction of the hip abductors in order to reduce hip loading, and thus reduce pain. Others believe that hip abductor weakness is an effect of surgery seeing that the lateral surgical approach to THA involves the detachment (and repair) of the anterior third of the gluteus medius. We suggest that the deficiency observed in the hip abductors of the THA patients is a result of both these occurrences. Given that Foucher and colleagues (2007) found that post-surgery hip abduction moments were not correlated with pre-surgery moments in THA patients performing the task of walking, pre-surgery disuse muscle atrophy cannot be entirely responsible for the lower hip abduction moments measured post-surgery in THA patients. Consequently, a portion of the group differences in hip abduction moments could be explained by the surgical approach utilized by the surgeons – the lateral approach, which disturbs the hip abductors. A comparison of the presented data with those from THA patients for which an anterior approach to surgery was used would potentially support our explanation regarding the origin of hip abductor weakness exhibited in THA patients. This is being currently addressed in an ongoing study. Nonetheless, a weakness of the musculature surrounding the hip joint may reduce the protection of the surface on which the implant is affixed, especially during athletic activities, and thus be detrimental to implant longevity. Given that athletic activities are generally more physically demanding than level walking, these gait deficiencies found to be present in THA patients may be amplified during sports, especially during those that require walking and/or running as the mean of locomotion It becomes imperative, therefore, for patients to follow a post-surgery rehabilitation program with a particular focus on muscle strengthening, especially of the hip abductors.

Furthermore, this strategy seemed to have coincided with an adaptation in transverse plane ankle mechanics. It seemed to demand a less externally rotated ankle – the result of an increase in ankle internal rotation moment produced by the THA patients. It is unclear, however, what consequences, if any, these greater ankle transverse plane moments may eventually have on the health of the musculoskeletal system. It was also found that the THA patients displayed lower hip, knee and ankle resultant inter-segmental joint forces than the control participants (Table 1). Hence, the former group exhibited a joint loading strategy that favoured unloading of the affected limb. Since these forces are highly dependent on those produced by the musculature surrounding the joints, THA patients displayed a reduction in not only hip, but also knee and ankle joint muscle activation, in comparison with their healthy, matched counterparts, as they transitioned from double- to single-limb stance of walking. This may be a result of the deficient frontal plane hip moments produced by the THA patients that propagated to the neighbouring joints. These differences in gait loading pattern at all three joints of the lower limb between the THA and control groups only reinforce a need for a rehabilitation program which addresses these muscle strength deficits. By neglecting such deficits, THA patients run the risk of prolonging their inferior ability to perform daily living and athletic activities, as well as the risk of jeopardizing the longevity of their implant.

CONCLUSION: Consequently, the results of the present study reveal that the gait mechanics of patients walking on a level surface do not return to normal following total hip arthroplasty. This was found to be particularly true as the THA patients transitioned from double- to single-limb stance. During this portion of the gait cycle, these patients produced lower hip abduction moments that are presumably consequential to hip abductor strength deficiencies or a preconditioning of the hip muscles. Moreover, gait mechanics at the distal joint were also affected. For these reasons, hip musculature deficiencies should be addressed in rehabilitation programs prior to and after THA, especially if patients want to return to athletic activities since these are generally more demanding than walking on a flat surface.

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