INTRODUCTION

Total hip arthroplasty (THA) is a common surgery for a deteriorated hip joint to effectively regain its functions. Patients underwent THA are reported to have a higher risk of falling due to the residual deficits in balance control and joint function [1]. Previous gait analyses of THA patients were mainly focused on the kinematics and kinetics of individual joint. However, human gait is a complex task requiring a precise end point motor control that is accomplished by a multi-joint coordination. Inconsistency in such coordination may induce gait deviations [2]. Investigating the inter-joint coordination during gait would help us to identify changes in neuromuscular control strategies due to hip joint dysfunction. The purpose of this study was to investigate the patterns and variability of inter-joint coordination for both surgical and non-surgical limbs of THA patients during walking.

METHODS

Thirty adults were recruited and divided into two groups in this study. Twenty patients underwent unilateral THA (15 male, 5 female, age = 56.5 ± 5.4 yrs, BMI = 32.6 ± 4.0 kg/m²), and 10 subjects served as age-matched controls (5 male, 5 female, age = 59.9 ± 5.3 yrs, BMI = 26.3 ± 3.9 kg/m²). THA patients were tested three times at pre-surgery, 6-weeks and 16-weeks post surgery, respectively. All patients received the same un-cemented Zimmer hip implants and followed the same physical therapy regimens during the study period. Control subjects were tested twice with one month apart.

An eight-camera motion analysis system (Motion Analysis Corp., Santa Rosa, CA) was used to collect the whole body motion during level walking at self selected pace. A total of 29 reflective markers were placed on bony landmarks. Joint kinematics of the bilateral lower extremities was calculated by using OrthoTrak kinematic analysis software (Motion Analysis Corp).

Continuous related phase (CRP), which is derived from the phase portraits of two adjacent joints, was used to investigate the inter-joint coordination pattern and variability [3]. Between groups differences in CRP pattern were examined by using cross-correlation measures and root-mean-square (RMS) difference to compare the ensemble mean curves of THA group to the controls. The variability of coordination for each subject was calculated as average standard deviation of every point on the ensemble CRP curve over a stride, namely deviation phase (DP). A mixed-model analysis of repeated measures was used to analyze the effects of groups and time on DP. If significant differences are detected, a post-hoc analysis with gait velocity as a covariate was performed to further examine the role walking speed on detected group differences. Significance level was set at 0.05.

RESULTS AND DISCUSSION

At pre-surgery and 6-week post surgery, gait velocities of THA group (1.05 ± 0.25 m/s and 1.09 ± 0.22 m/s, respectively) were significantly slower than that of the controls (1.29 ± 0.17 m/s) (p<0.01). However, no significant differences were detected between two groups at 16-week post surgery. Significant time effects on gait velocity were detected in THA patients at 16-week post surgery (1.23 ± 0.15 m/s) when compared to pre-surgery and 6-week post surgery (p<0.005).

RMS differences for hip-knee and knee-ankle CRP decreased gradually after THA surgery for both surgical and nonsurgical limbs (Fig. 1). The surgical limb remained a greater RMS difference than nonsurgical limb at 6- and 16-week post surgery.
Cross-correlation measures were overall strong for CRP patterns of both limbs, with \(r^2\) values greater than 0.94, and were improved after surgery (Fig. 2).

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**Figure 1:** RMS differences (degrees) for CRP patterns between controls and THA.

**Figure 2:** Cross-correlation \(r^2\) for CRP patterns between controls and THA.

The variability for CPR is shown in Table 1. The surgical and nonsurgical limbs of THA group had higher DP values comparing to the controls at pre-surgery and 6-week post surgery. Of the surgical limb, significant group differences in hip-knee DP values were detected at pre-surgery, and significant group differences in knee-ankle DP values were detected at both pre-surgery and 6-week post surgery. Compared to pre-surgery, significant time effects on THA patients were detected in hip-knee DP values at 16-week post surgery for both limbs, and in knee-ankle DP values at 16-week post surgery for surgical limb.

**CONCLUSIONS**

Our results suggest that adjustments in inter-joint coordination of THA patients occurred at both surgical and nonsurgical limbs in responses to a deteriorated hip joint. The hip-knee and knee-ankle coordination demonstrated a higher variability to compromise this constrained hip joint, especially in the surgical limb. Asymmetric changes in accommodations and variability of bilateral lower extremities may contribute to the residual gait problems observed in THA patients. Therefore, clinical efforts may exert to improve the inter-joint coordination in this population.

**REFERENCES**


**ACKNOWLEDGEMENTS**

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**Table 1:** DP values for CRP curves of controls and THA

<table>
<thead>
<tr>
<th>Control</th>
<th>Non surgical</th>
<th>THA</th>
<th>Surgical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-surgery</td>
<td>6-week post surgery</td>
<td>16-week post surgery</td>
</tr>
<tr>
<td>Hip-Knee</td>
<td>30.63 (7.22)</td>
<td>41.14 (17.87)</td>
<td>40.05 (28.79)</td>
</tr>
<tr>
<td>Knee-Ankle</td>
<td>38.47 (6.32)</td>
<td>48.32 (18.93)</td>
<td>47.14 (25.65)</td>
</tr>
</tbody>
</table>

* significant group difference; † comparing to pre-surgery; # comparing to 6-week post surgery