ARTICLE IN PRESS

Journal of Biomechanics ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech
www.JBiomech.com

Short communication

Gait abnormalities before and after total hip arthroplasty differ in men and women

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ARTICLE INFO

Article history:
Accepted 7 September 2016

Keywords:
Total hip replacement
Gait
Sex differences
Biomechanics
Recovery of function

ABSTRACT

This study tested the hypothesis that men and women have different preoperative and postoperative gait impairment relative to sex-matched healthy controls, and that the extent of gait improvement after total hip arthroplasty (THA) is different between men and women. A group of 124 THA subjects was identified from a motion analysis data repository; age and BMI-matched male and female control groups were then identified from the same repository. Dynamic sagittal plane hip range of motion (HROM) and peak 3D external moments at subjects' normal walking speeds were analyzed. Each hypotheses was tested using linear regression models, to adjust for potential confounding effects of walking speed. Preoperatively, the THA vs. control group differences in the HROM and peak adduction moments were larger in women than they were in men ($p=0.007$). The THA group vs. control group difference in the peak external rotation moment was larger in men ($p=0.004$). After surgery, HROM increased more in women than in men ($p=0.020$). However, peak adduction moment decreased in men but increased in women (-0.11 ± 0.93 vs. 0.28 ± 1.3%BWH, $p=0.045$). Accordingly, postoperatively the THA group vs. control group differences in the peak external rotation moment remained larger in men than in women ($p=0.016$). There were no other sex-specific differences ($p=0.072$–0.876). This study suggests that men and women have slightly different patterns of gait recovery after THA and may benefit from sex-specific rehabilitation strategies. These differences also underscore the importance of accounting for sex in biomechanical studies.

1. Introduction

Gait analysis has been used for decades to quantify biomechanical abnormalities before and after total hip arthroplasty (THA). Although gait mechanics are known to differ in healthy men and women (Boyer et al., 2008; Ko et al., 2011; Moisio et al., 2003), sex differences in gait mechanics of THA patients have not been explicitly explored. There are potential implications for THA outcomes. The etiology of many adverse outcomes of THA (for example aseptic loosening, dislocation, and poor clinical outcomes) is at least partially related to joint mechanics. Thus, sex differences in gait can potentially alter the risk of these adverse outcomes. Indeed, sex differences in the rates of certain THA complications have been reported (Inacio et al., 2013; Katz et al., 2012; Mahomed et al., 2003; Prokopetz et al., 2012). Understanding how sex differences may influence gait mechanics in THA patients can ultimately lead to improved identification, treatment, or prevention of adverse outcomes.

The purpose of this secondary analysis was to explore sex differences in gait mechanics before and after THA. The rationale was that identifying such differences could suggest a potential need for sex-specific strategies to reduce revision risk and improve clinical outcomes. Accordingly, in this study the hypotheses tested were that: (1) Gait abnormalities (differences compared to sex-matched healthy controls) are not the same in men compared to women before THA; (2) The extent to which THA alters gait mechanics is different in men and women; and (3) Gait abnormalities (differences compared to sex-matched healthy controls) are not the same in men compared to women after THA.

2. Methods

2.1. Subjects

The cohort of THA subjects was most recently described in a study of preoperative and postoperative gait mechanics (Foucher and Freels, 2015). Briefly, an IRB-approved data repository was used to identify subjects. Data were pooled from several previous studies. Relevant inclusion and exclusion criteria for the original studies include candidacy for primary unilateral THA, no other planned or anticipated joint surgeries, and no symptoms in any other lower extremity joint at the time of enrollment. All original studies also excluded patients with a diagnosis of inflammatory arthritis or a recalled history of hip trauma. The inclusion criterion

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http://dx.doi.org/10.1016/j.jbiomech.2016.09.003
0021-9290/© 2016 Published by Elsevier Ltd.

Table 1
Characteristics of the THA ($N=124$) and control ($N=95$) groups by sex.

	THA group men	Control group men	p value (THA men vs. control men)	THA group women	Control group women	p value (THA women vs. control women)
Age in years Mean (SD)	58.2 (10.7)	55.9 (8.1)	0.204	62.2 (9.9)	60.4 (7.1)	0.231
BMI in kg/m² Mean (SD)	29.2 (4.7)	28.8 (3.1)	0.600	27.7 (5.8)	26.4 (5.2)	0.163

for the present analysis was availability of both preoperative and postoperative gait analysis data in the repository. For subjects who were evaluated more than once after surgery, the 1-year follow-up time point was selected. Minimum follow-up time was 6 months.

The pool of control subjects were from the same IRB-approved data repository, and were most recently described in a study comparing gait mechanics of subjects with and without hip osteoarthritis (Foucher et al., 2012). Subjects were identified from the community and were required to have no current musculoskeletal complaints or history of osteoarthritis or other major joint conditions by self-report. For this study, subjects were selected from this healthy cohort to form a male and a female age- and BMI-matched control group for each respective THA group (Table 1). In this manner, 124 THA subjects (60 men, 64 women) and 95 control group subjects (31 men, 64 women) were identified for the present analysis.

Harris Hip Scores (HHS) were used to characterize clinical status (i.e. pain, function, etc.) of THA subjects at each visit to the gait analysis lab (Harris, 1969; Soderman and Malchau, 2001). Based on t-tests, there were no statistically significant differences between preoperative HHS scores between sexes (men HHS$=59\pm15$, women HHS$=55\pm12$, $p=0.158$). As a group, subjects had clinically well-functioning implants after surgery. There were no statistically significant differences between postoperative HHS scores between sexes (men HHS$=93\pm10$, women HHS$=90\pm11$, $p=0.098$).

2.2. Gait analysis

Gait analyses was conducted using standard methods previously described (Andriacchi et al., 2005; Hurwitz et al., 1998) and the same methodology for all subjects. Briefly, a multicomponent forceplate (Bertec, Columbus OH) measured ground reaction forces as subjects walked across a 10 m walkway. An optoelectronic camera system (Qualisys North America, Deerfield IL) tracked the motion of reflective markers placed at bony landmarks of the lower extremities. The ankle joint center was considered to be at the midpoint of the lateral and medial malleoli; this distance was measured using calipers. The knee joint center was considered to be at the midpoint of the joint line; the joint line was located by palpation as subjects flexed and extended the knee, and was then measured with calipers as at the ankle. To identify the superior–inferior and medial-lateral position of the hip center, we determined the point 2.5 cm inferior to the midpoint of the distance between the anterior superior iliac spine and the pubic tubercle, which were identified by palpation. The anterior–posterior position was deemed to be at the AP location of the superiormost aspect of the greater trochanter. This point was found by palpation as subjects moved through hip abduction–adduction and internal-external rotation within their pain-free range. Custom software (CFTC — Computerized Functional Testing Corporation, Chicago, IL) was used to determine spatiotemporal gait variables and sagittal plane joint kinematics, from marker positions, and to calculate external moments in the sagittal, frontal, and transverse planes, using inverse dynamics. Moments were normalized to subject body weight and height (%BWH). In this study, the variables of interest were thy dynamic hip range of motion in the sagittal plane (HROM) and peak 3D moments about the hip, averaged from self-selected normal speed trials.

2.3. Statistical analysis

Analyses were conducted using SPSS V.22 (IBM SPSS Statistics, Chicago, IL). The hypotheses were all addressed using linear regression models so that the potentially confounding effect of speed could be accounted for. First, to evaluate hypothesis 1 – that gait abnormalities (differences compared to sex-matched healthy controls) are not the same in men compared to women before THA – models were constructed in which each preoperative gait variable was the dependent variable, and speed, sex, and sex by group (control or THA) were the predictor variables. To test hypothesis 1, we checked for statistically significant sex by group interaction terms. Next, to evaluate hypothesis 2 – that the extent to which THA alters gait mechanics is different in men and women – models were constructed in which the pre-to-postoperative change (Δ) in each gait variable was the dependent variable and sex, baseline gait, and Δspeed were the predictor variables. To test hypothesis 2, we checked for a significant main effect of sex in the model for the respective gait variable. Finally, to evaluate hypothesis 3 – that gait abnormalities (differences compared to sex-matched healthy controls) are not the same in men compared to women after THA, models were constructed in which each postoperative gait variables was used as the dependent variable, and speed, sex, and sex by group (control vs. THA) interaction were the predictor variables. To test hypothesis 3, we again checked for statistically significant sex by group interaction terms. By convention, $p<0.05$ was considered statistically significant.

3. Results

3.1. Are gait abnormalities the same in preoperative men vs. preoperative women?

There were significant sex by group interactions for preoperative sagittal plane hip range of motion, peak adduction and peak external rotation moments ($p=0.004$–0.008) Women THA candidates had greater reductions in hip range of motion and adduction moments compared to control group women (Fig. 1). Male THA candidates had greater reductions in external rotation moments (Fig. 1). There were no other statistically significant sex by group interactions ($p=0.349$–0.997), but there were significant THA candidate vs. control group main effects for all remaining variables.

3.2. Does THA change gait mechanics to the same extent in men and women?

The effects of THA on the sagittal plane HROM and the peak hip adduction moment were different in men and women (Fig. 2). While sagittal plane HROM increased for both, the increase was slightly smaller in men ($7.9\pm5.2°$ vs. women $10.1\pm5.9°$, $p=0.021$). The peak hip adduction moment decreased after THA in men, but increased in women (-0.11 ± 0.93 vs. 0.28 ± 1.3%BWH, $p=0.045$). This difference was statistically significant ($p=0.045$) but it is important to note that there was considerable variability in the relative improvement in this variable in both groups, as indicated by the wide standard deviations. There were no other statistically significant differences in gait changes after THA between sexes ($p=0.072$–0.826).

3.3. Are gait abnormalities the same in postoperative men vs. postoperative women?

The difference in the peak external rotation moments in postoperative men vs. male control subjects was larger than the difference in that variable between postoperative women and female control subjects ($p=0.016$). Post-THA men had an external rotation moment that was 41% less than that of control group men (0.44 ± 0.23%BWH vs. 0.72 ± 0.32%BWH). Post-THA women had an external rotation moment that was 35% less than that of control group women (postop women 0.40 ± 0.22%BWH, control women 0.62 ± 0.32%BWH, $p=0.016$). There were no other statistically significant group by sex interactions (all other variables $p=0.299$–1.0). Also of note, as a result of the slightly larger change in HROM values for the women, the postoperative value of this variable showed no significant sex by group interaction. There were significant THA vs. control group main effects for postoperative hip range of motion, peak adduction, internal rotation and external rotation moments, ($p<0.001$). These variables were all reduced compared to normal,

Please cite this article as: Foucher, K.C., Gait abnormalities before and after total hip arthroplasty differ in men and women. Journal of Biomechanics (2016), http://dx.doi.org/10.1016/j.jbiomech.2016.09.003