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Sex-specific hip osteoarthritis-associated gait abnormalities: Alterations in dynamic hip abductor function differ in men and women

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ABSTRACT

Background: Hip osteoarthritis results in abnormal gait mechanics, but it is not known whether abnormalities are the same in men and women. The hypothesis tested was that gait abnormalities are different in men and women with hip osteoarthritis vs. sex-specific asymptomatic groups.

Methods: 150 subjects with mild through severe radiographic hip osteoarthritis and 159 asymptomatic subjects were identified from an Institutional Review Board-approved motion analysis data repository. Sagittal plane hip range of motion and peak external moments about the hip, in all three planes, averaged from normal speed walking trials, were compared for men and women, with and without hip osteoarthritis using analysis of variance.

Findings: There were significant sex by group interactions for the external peak hip adduction and external rotation moments ($P = 0.009–0.045$). Although asymptomatic women had peak adduction and external rotation moments that were respectively 12% higher and 23% lower than asymptomatic men ($P = 0.026–0.037$), these variables did not differ between men and women with hip osteoarthritis ($P \geq 0.684$). The osteoarthritis vs. asymptomatic group difference in the peak hip adduction moment was 45% larger in women than in men. The osteoarthritis vs. asymptomatic group difference in the peak hip external rotation moment was 55% larger for men than for women ($P < 0.001$). Sex did not influence the association between radiographic severity and gait variables.

Interpretation: Normal sex differences in gait were not seen in hip osteoarthritis. Sex-specific adaptations may reflect different aspects of hip abductor function. Men and women with hip osteoarthritis may require different interventions to improve function.

1. Introduction

Hip osteoarthritis (OA) is associated with abnormal gait mechanics (Ardestani and Wimmer, 2016, Chabra and Foucher, 2013, Chabra et al., 2012, Constantinou et al., 2014, Eitzen et al., 2012, Eitzen et al., 2015, Foucher et al., 2012, Hurwitz et al., 1997, Kumar et al., 2015b, Leigh et al., 2016, Rutherford et al., 2015, Watelain et al., 2001). There is overlap between the gait variables that have been found to differ between people with and without hip OA and those that differ between healthy men and women. For example, reduced dynamic sagittal plane hip range of motion (Eitzen et al., 2012; Foucher et al., 2012; Hurwitz et al., 1997; Hurwitz et al., 1998; Watelain et al., 2001), and reductions in the peak external hip adduction moment (Ardestani and Wimmer, 2016; Foucher et al., 2007; Foucher et al., 2011; Hurwitz et al., 1997; Hurwitz et al., 1998) are commonly seen in hip OA. These same variables reportedly differ between healthy men and women (Boyer et al., 2008; Kerrigan et al., 1998; Ko et al., 2011b; Moisio et al., 2003). Moreover, it has been shown that knee OA affects gait in sex-specific ways (Ko et al., 2011a; Kumar et al., 2015a; McKean et al., 2007; Phinyomark et al., 2016). There may be sex-specificity in hip OA gait abnormalities as well. If so, there may be a need for sex-specific biomechanically-based interventions to improve function in men and women with hip OA.

Because of a dearth of sex-specific analyses in the hip OA biomechanics literature, the aim of this study was to identify sex-specific hip OA-related gait abnormalities in a previously described cohort of subjects with and without hip OA (Foucher et al., 2012). The hypothesis tested was that men with hip OA, when compared to asymptomatic men, would have different gait abnormalities than women with hip OA compared to asymptomatic women. Although there was no a priori expectations regarding the specific variables, or the direction or magnitude of the differences, the sagittal plane hip range of motion and peak external hip adduction moment were of particular interest. These variables are known to be different in healthy men and women, and are

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Table 1
Subject characteristics.

	Hip osteoarthritis			Asymptomatic				
	Women (N = 86)	Men (N = 64)	*P* value	Women (N = 104)	Men (N = 55)	*P* value	OA vs. asymptomatic women	OA vs. asymptomatic men
Age (yrs)	63.5 (SD 9.1) (44–85)	60.6 (SD 10.8) (29–79)	0.082	55.6 (SD 8.6) (41–78)	55.8 (SD 8.0) (42–80)	0.869	< 0.001	0.008
BMI (kg/m^2)	27.8 (SD 5.5) (16.1–46.3)	28.9 (SD 4.6) (21.8–41.9)	0.190	26.6 (SD 5.9) (16.5–46.9)	26.8 (SD 3.7) (21.4–36.3)	0.818	0.141	0.006
Walking speed (m/s)	1.0 (SD 0.2) (0.3–1.5)	1.1 (SD 0.2) (0.4–1.4)	0.009	1.3 (SD 0.2) (0.8–1.9)	1.4 (SD 0.2) (0.8–1.9)	0.195	< 0.001	< 0.001
KL grade (N)	KL 1: 6 KL 2: 9 KL 3: 24 KL 4: 47	KL 1: 0 KL 2: 3 KL 3: 7 KL 4: 54	0.001					

both linked to hip OA. Other gait variables discussed in the parent publication (Foucher et al., 2012), were included as well. Within the OA group, interactions between sex and radiographic OA severity were also investigated.

2. Methods

2.1. Subjects

An Institutional Review Board-approved data repository was used to identify 150 subjects with symptomatic, radiographically-verified hip OA. 159 asymptomatic subjects were identified from the same repository by selecting subjects whose ages were within two standard deviations of the mean age of the hip OA group. All subjects provided written informed consent for the original studies in which they were enrolled, and for the inclusion of their data in the repository, for secondary analyses. Asymptomatic subjects were slightly younger and had lower Body Mass Indices (BMIs) ($P \leq 0.006$) than the subjects with hip OA, but these differences did not influence the results of the previous study (Foucher et al., 2012). This difference persisted when the groups were separated by sex (Table 1), so these factors were considered in the statistical analysis. For the hip OA subjects, radiographic severity information was included in the database. A modified Kellgren-Lawerence (KL) grading system (0 – no OA to 4 – most severe) had been used to rate the severity of the osteoarthritic changes from Anterior-Posterior pelvic radiographs that were originally obtained for clinical purposes. The rater was a rheumatologist who was aware of a subject's status as an OA patient, but not necessarily aware of their participation in a research study.

2.2. Gait analysis

Previously published (Foucher et al., 2012) gait analysis data were used. Methods have been described in detail elsewhere (Andriacchi, 1990; Andriacchi et al., 2005; Hurwitz et al., 1998). Briefly, an optoelectronic camera system (Qualisys North America, Deerfield IL) tracked the motion of reflective markers placed at bony landmarks, while a multicomponent forceplate (Bertec, Columbus OH) measured ground reaction forces as subjects walked across a 10 m walkway at self-selected speeds of slow, 'normal', and fast. Between 2 and 8 trials for each limb were collected at the self-selected normal walking speed, depending on the protocol of the original study. These trials were selected for the present analysis. To identify the ankle and knee joint centers, calipers were used to measure the width of the respective joint (distance from medial to lateral malleoli and the width of the knee at the joint line). The anterior-posterior position of the hip center was assumed to be at the location of the superiormost aspect of the greater trochanter, which was located by palpation and indicated with a marker. The superior-inferior position was determined by location a 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. 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. For the OA subjects, we selected data from the affected hip side. For the asymptomatic subjects, a random study limb was selected. There were no differences between the distribution of right and left limbs between the hip OA group and the asymptomatic group (Chi-square $P = 0.452$).

The variables of interest here were the dynamic sagittal plane range of motion (RoM) and the peak external moments about the hip joint in the sagittal, frontal, and transverse planes, as in the parent study (Foucher et al., 2012). These variables were averaged from normal speed walking trials. External moments were normalized to subjects' body weight and height (%BWH) (Moisio et al., 2003).

2.3. Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics V.24 (IBM Corporation, Armonk, NY). Two way ANOVAs were used to compare gait variables for men and women, with and without hip OA. Sex, group (OA vs. Control), and a sex by group interaction term were included in the models. Age, BMI, and walking speed were included as covariates. For each gait variable, a statistically significant ($P < 0.05$) sex by group interaction term indicated that the difference between OA and control subjects varied between men and women. Effect sizes (Cohen's d) were calculated and post-hoc *t*-tests were used to assess the magnitude of the difference. This analysis was repeated within the OA group, using KL grade as the grouping variable and a KL by sex interaction term.

3. Results

In the sagittal plane (dynamic hip range of motion and peak external hip flexion and extension moments), there were no statistically significant sex by group interaction terms (respectively, $P = 0.895$, 0.052, 0.409; Table 2). All three variables were significant lower in the OA group than in the asymptomatic group (main effect of group $P < 0.001$). There was a significant main effect of sex for the dynamic sagittal plane hip RoM ($P < 0.001$) and peak external hip extension moment ($P = 0.030$). In both the OA and the asymptomatic groups, values of these variables were higher for women than men (Fig. 1). There were no sex differences for the peak external hip flexion moment ($P = 0.389$).

In the frontal plane (peak external hip adduction and abduction moments), there was a significant sex by group interaction term for the peak external hip adduction moment only ($P = 0.045$; Table 2). Asymptomatic women had a peak external hip adduction moment that was 13% higher than asymptomatic men (d = 0.54, $P = 0.002$). By