Journal of Electromyography and Kinesiology 25 (2015) 944–950

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Hip joint motion and gluteal muscle activation differences between healthy controls and those with varying degrees of hip osteoarthritis during walking

Derek J. Rutherford [a,b,c,*], Janice Moreside [a,b], Ivan Wong [a,b,d]

[a] School of Physiotherapy, Faculty of Health Professions, Dalhousie University, Halifax, NS, Canada
[b] School of Health and Human Performance, Faculty of Health Professions, Dalhousie University, Halifax, NS, Canada
[c] School of Biomedical Engineering, Faculty of Engineering, Dalhousie University, Halifax, NS, Canada
[d] Department of Surgery, Division of Orthopaedics, Dalhousie University, Halifax, NS, Canada

ARTICLE INFO

Article history:
Received 11 May 2015
Received in revised form 13 October 2015
Accepted 14 October 2015

Keywords:
Hip osteoarthritis
Gait analysis
Range of motion
Electromyography
Gluteus medius
Gluteus maximus
Principal component analysis

ABSTRACT

Purpose: Compare gluteal muscle activation patterns and three-dimensional hip joint movements among those with severe hip osteoarthritis (OA), moderate OA and a healthy group during walking. *Scope:* 20 individuals with severe OA, 20 with moderate OA and 20 healthy individuals were recruited. Three-dimensional hip motion and surface electromyograms from gluteus maximus and medius were collected during treadmill walking at a self-selected speed. Angular displacement characteristics were calculated for three-dimensional hip motions. Principal component analysis extracted amplitude and temporal features from electromyographic waveforms. Analysis of Variance models and student *t*-tests using Bonferroni corrections determined between group differences in these gait features ($\alpha = 0.05$). *Conclusions:* Sagittal plane hip range of motion was significantly reduced with increasing severity of OA ($p < 0.05$) where as frontal and transverse plane range of motion was reduced in the severe OA group only ($p < 0.05$). Activation patterns of gluteus medius and maximus did not differ between the healthy group and those with moderate hip OA ($p > 0.05$). Individuals with severe OA walking with more prolonged gluteus maximus activation and prolonged and less dynamic gluteus medius activation compared to the other two groups ($p < 0.05$). This study highlights the changing function of the hip joint during walking with increasing hip OA severity.

1. Introduction

Lower extremity osteoarthritis (OA) is a leading cause of impaired mobility in older adults. In Canada, joint replacement surgeries for hip OA have increased over 60% in the last decade (CIHI, 2013) as many see it as a way to reduce the pain associated with the disease, thus allowing them to remain active. Hip OA is thought to result from a failed repair of the hip joint, secondary to mechanical stressors (Felson, 2013). Quantifying hip joint function as it pertains to mobility in individuals with OA may provide an objective metric to aid understanding joint stresses during walking; a familiar activity that many individuals with OA struggle with.

Individuals with hip OA typically walk with reduced sagittal plane hip motion (Hurwitz et al., 1997; Foucher et al., 2012; Eitzen et al., 2012). A brief reversal of hip extension during midstance has also been found in individuals with severe hip OA (Foucher et al., 2012). Eitzen et al. (2012) found that sagittal plane hip movement was dependent on radiographic severity; individuals with severe disease walked with less hip extension during late stance than those with mild disease or asymptomatic individuals and no motion reversals were reported. Despite evidence that hip joint function is altered with OA presence, it is still unclear how three-dimensional movements during walking change over the spectrum of increasing hip OA severity.

Kinematics provide an analysis of joint dysfunction during gait but do not aid our understanding of underlying mechanisms. Muscles can control joint motion, and thus may provide information on potential mechanisms for altered movement. Unfortunately, the inter-relationships between hip joint motion and gluteal muscle activation remain unclear. Dwyer et al. (2013) found greater hip

* Corresponding author at: School of Physiotherapy, 4th Floor Forrest Building, Dalhousie University, 5869 University Ave, PO Box 15000, Halifax, NS, Canada. Tel.: +1 902 494 4248; fax: +1 902 494 1941.

E-mail addresses: djr@dal.ca (D.J. Rutherford), jmoreside@dal.ca (J. Moreside), iw@drivanwong.com (I. Wong).

http://dx.doi.org/10.1016/j.jelekin.2015.10.010
1050-6411/

abductor activation throughout gait in 13 individuals with end-stage unilateral hip OA compared to healthy adults. Others have found that gluteal activation remains abnormal in individuals following hip arthroplasty (Agostini et al., 2014). While altered muscle activation is thought to be a mechanism to stabilize the deteriorating joint, greater muscle activity may increase hip joint compressive forces, ultimately affecting joint health (Neumann and Hase, 1994) and long-term function (Sims, 1999). However, to our knowledge, this has not been comprehensively studied during gait and it is unknown how gluteal muscle activation patterns are altered as a result of increasing hip OA severity.

At this time, there is a lack of understanding of hip joint motion and gluteal muscle activation patterns during gait when comparing individuals with severe hip OA to those with moderate hip OA or those with no symptoms of OA. The objectives of this investigation were to determine whether three-dimensional (3D) hip range of motion (ROM) and patterns of gluteal muscle activation are different between those with severe and moderate OA, and when compared to a healthy group. It is hypothesized that as severity increases, the hip joint will become stiffer, resulting in reduced 3D motion and less dynamic, more prolonged stance phase gluteal muscle activation.

2. Methods

2.1. Participants

Participants with unilateral symptomatic hip OA were recruited over 1 year (2013–14) from local orthopaedic clinics after consultation with an orthopaedic surgeon regarding hip arthroscopy for early disease management (moderate OA) and met a functional criteria previously used to define moderate knee OA (Rutherford et al., 2013) or were candidates for total hip replacement (severe OA). Participants were excluded from the moderate OA group if they were candidates for total hip replacement. Hip OA was determined using the American College of Rheumatology criteria (Altman, 1991). The healthy group was recruited from the general community using email and website based advertisements and considered a sample of convenience. These individuals had no pain in the ankles, knees or hips during testing and no symptoms of lower extremity OA. All participants were $\geqslant$50 years of age, had no fracture or injury other than a sprain or strain (within one year) or no previous knee/hip joint surgery. All had to be able to walk independently, with no neurological or cardiovascular disorders that would impair walking ability. The protocol was approved by the local institutional ethics review committee (NSHA-RS/2014-081) and participants provided written informed consent.

Standard A/P pelvis and lateral radiographs were used to describe hip OA radiographic severity. A single experienced reader (IW), who was blinded to participant identification and gait analysis outcomes at the time of scoring, graded radiographs using the Kellgren–Lawrence (KL) ordinal radiographic scale (Kellgren and Lawrence, 1957). Participants in the healthy group did not receive any radiographs.

2.2. Procedures

Participants changed into a T-shirt and fitted shorts, removed their footwear and completed at least five self-paced walking trials across the GaitRITE™ portable pressure sensitive walkway (CIR Systems, Clifton, NJ, USA) to determine average self-selected gait speed.

Following these trials, participants were prepared for surface electromyography (EMG); skin was lightly shaved and cleaned with 70% alcohol wipes. Consistent with guidelines (Hermens et al., 2000) and standard procedures, Ag/AgCl surface electrodes (10 mm diameter, 30 mm inter-electrode distance, Red Dot, 3 M Health Care, St. Paul MN, USA) were placed in a bipolar configuration over the gluteus medius (GMd) – 50% of the distance from the iliac crest to the ipsilateral greater trochanter, and gluteus maximus (GMx) – 50% of the distance between the 2nd sacral vertebrae and the greater trochanters. Muscle palpation and a series of isometric contractions for specific muscle groups were used for signal validation and gain adjustment. Surface EMG was recorded at 2000 Hz using an AMT-8™ Bortec system (Bortec Inc. Calgary) (Input Impedance: $\sim$10 GΩ, CMRR: 115 dB at 60 Hz, Band-pass (10–1000 Hz), Gain Range 500–5000$\times$) and custom LabVIEW™ 2013 programs (National Instruments Corporation, Austin, TX).

Rigid sets of four retro-reflective markers were affixed to the mid-dorsal trunk (level of the inferior scapular angles), the pelvis (atop the sacrum), posterior femur and tibia using Velcro straps and secured with adhesive tape. Single retro-reflective markers were placed over the lateral aspect of the shoulders (below acromion), atop the spinous process of the 7th cervical vertebra, greater trochanters, medial and lateral femoral and tibial epicondyles, medial and lateral malleoli, head of the 5th metatarsal, and posterior heel.

Prior to gait analysis, a kinematic model calibration was completed, including a standing calibration trial, a virtual sternum, two virtual anterior superior iliac spine location trials and two standing hip joint center calculation trials that required the subject to move each leg through hip flexion, abduction and extension (Camomilla et al., 2006). Markers over the greater trochanters, medial tibial and femoral epicondyles, lateral tibial epicondyles and medial malleolus were then removed. Retro-reflective skin marker motion was captured at 50 Hz using four Qualisys® Pro-reflex motion analysis sensors (Gothenburg, Sweden).

Participants began walking on the treadmill at the self-selected GaitRITE™ walkway speed for at least four minutes for accommodation/warm-up. Following this, three 20-s data collections were completed, with approximately one minute between collections, during which the participants continued walking, thus blinded to collection intervals. After completion, retro-reflective markers were removed and a resting muscle activity trial (EMG subject bias) was recorded with the participant lying supine. Electrodes were subsequently removed.

Prior to completing the study, all participants completed the Hip Outcome Osteoarthritis Score (HOOS), which was scored based on instructions provided at www.koos.nu. The International Hip Outcome Tool (iHOT-33) was scored according to Mohtadi et al. (2012). For both questionnaires, a higher score indicates a better outcome.

2.3. Data analysis

Raw EMG signals were first processed to minimize the effects of treadmill noise contamination. This included, (i) band pass filtering (4th order Butterworth) with a pass band from 20 to 500 Hz (De Luca et al., 2010) and (ii) band-stop filtering at 60 Hz (and harmonics) in the frequency domain (using Fast Fournier Transformation, FFT and following inverse FFT). All EMG signals were then corrected for resting bias, converted to micro-volts, full-wave rectified and filtered using a Butterworth, 6 Hz recursive, 4th order, low-pass filter. Compared to the 10 Hz high pass cut off recommended by the Journal of Electromyography and Kinesiology, the 20 Hz setting used in the current band pass filter settings did not influence the interpretation of the results in this manuscript. All EMG waveforms were amplitude normalized to the peak EMG amplitude obtained for each muscle during the gait cycle (Burden, 2010).

Technical and local anatomical bone embedded coordinate systems for the pelvis, thigh, and shank were derived from virtual