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Comparison of gluteus medius muscle activity during functional tasks in individuals with and without osteoarthritis of the hip joint

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ABSTRACT

Background: Neuromuscular alterations have been reported for patients with osteoarthritis of the hip joint; however, the underlying cause associated with altered gluteus medius muscle function has not been examined. This study assessed electromyographic amplitudes of the gluteus medius muscles during function in patients with unilateral end-stage osteoarthritis of the hip joint compared to controls.

Methods: Patients with unilateral end-stage hip joint osteoarthritis (n = 13) and asymptomatic control participants (n = 17) participated. Average root-mean squared muscle amplitudes represented as a percent of maximum voluntary isometric contraction for both the involved and uninvolved limb gluteus medius muscles were analyzed during step up, step down, and gait. The association between muscle activation and impact forces during stepping tasks was assessed.

Findings: Patients with hip osteoarthritis exhibited increased gluteus medius muscle electromyographic amplitudes bilaterally during stair ascent, stair descent, and gait compared to controls, regardless of which limb they led. Involved limb muscle activity was inversely related to impact force during step down onto the ipsilateral limb.

Interpretation: Patients with hip osteoarthritis demonstrated increased gluteus medius muscle activation levels during stepping tasks and gait when compared to controls. The increased activation is most likely a compensatory response to muscle weakness. Therefore, application of strengthening exercises which target the gluteal muscles should assist in neuromuscular control and result in improved strength for patients with hip joint osteoarthritis.

1. Introduction

Osteoarthritis (OA) of the hip joint is a frequent cause of functional disability in the young adult between 30–50 years of age. Joint pain, instability and muscle weakness have been identified as potential risk factors for functional decline in this population (Dekker et al., 2009; Felson and Zhang, 1998; Shindle et al., 2008). Continued function in the presence of neuromuscular alterations may hasten the progression of joint disease and results in functional alterations (Herzog et al., 2003; Shrier, 2004). For patients who present with end-stage hip osteoarthritis, biomechanical alterations exist during gait (Pustoc'h and Cheze, 2009; Watanabe et al., 1998) and stair climbing (Pustoc'h and Cheze, 2009), and these changes have been shown to directly correlate with hip abductor muscle weakness (Vaz et al., 1993). Alterations in the physiological properties of the gluteal muscles may account for the functional weakness, as fewer numbers and smaller cross-sectional areas of type II muscle fibers as well as reductions in the radiological density of the gluteus medius muscle have been observed for this population compared to control subjects (Arokoski et al., 2002; Rasch et al., 2009). However, limited research describing alterations in the neuromuscular function of this muscle associated with OA of the hip joint exists.

Previous research using surface electromyography (SEMG) reported alterations in timing and duration of gluteus medius activation during the gait of elderly subjects with advanced hip joint disease (Long et al., 1993) as well as increased muscle activity for the gluteus medius muscles of both limbs during stepping for subjects with early phase hip joint OA compared to healthy individuals (Sims et al., 2002). However, none of the previous studies reported the specific magnitude of difference between populations. Quantification of the amplitude of muscle activation during activity will assist in identifying the underlying cause for the observed muscle alterations. An increase in muscle activation levels may indicate a weak muscle, resulting from a compensatory increase in neural drive to achieve the required muscle force to complete the given task (Ling et al., 2007; Sims et al., 2002). Higher muscle activation during submaximal activities may also indicate an inability to fully activate due to pain. Contrary, a decrease in activation levels may indicate a reflexive inhibition of neural drive to the muscle, the body's protective response to joint injury (Hart et al., 2010) or lower demands

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to the muscle from lower body mass or improved neuromuscular control. As there is currently no cure for osteoarthritis, therapeutic options for young patients are few and often involve surgical interventions along with rehabilitation. A better understanding of the neuromuscular alterations and the subsequent biomechanical consequences during function associated with end-stage joint disease may facilitate the creation of appropriate rehabilitation programs. The purpose of our study was to compare average SEMG muscle amplitude of the gluteus medius muscles during function between adults with unilateral advanced phase hip joint OA and age-comparable healthy controls. Given that bilateral alterations in gluteus medius muscle activation have been reported for patients with early phase joint disease (Sims et al., 2002), we hypothesized that average gluteus medius muscle SEMG amplitudes will be increased for both the involved and uninvolved limb during gait and stepping tasks for individuals with hip OA compared to controls. In addition, we hypothesized that SEMG values of the gluteus medius muscles during stepping will be correlated with impact forces measured during these tasks.

2. Methods

2.1. Participants

Adults with unilateral, end-stage OA of the hip joint scheduled for total hip arthroplasty were recruited from the patient population of one of the authors (MG). Subjects were included if they presented with unilateral hip pain, were between 18 and 65 years of age, had no history of vestibular disorders, and presented with no major comorbidities. Subjects were excluded if they had symptomatic bilateral hip pain, any history of major lower extremity surgery, or current lower extremity injury. Healthy control subjects were recruited from the local area via internet advertisements and clinic posters. Subjects were considered for the control group if they reported no pain in either hip joint and had no history of major lower extremity injury or surgery. The analysis sample consisted of 13 patients with OA of the hip joint and 17 controls (Table 1). This research was approved by the university's Institutional Review Board.

2.2. Pain

Subjects were asked to rate their pain using the Visual Analog Scale (VAS). Hip symptoms were assessed by asking each subject "During the past 7 days, what is the highest level of pain experienced during your daily activities?" The VAS ranged from 0 to 10 cm, with 10 cm indicating worse pain.

2.3. Electromyography

A 16-lead SEMG system (Run Technologies, Mission Viejo, CA, USA) was used to record muscle activity. A Myopac transmitter belt unit (Run Technologies, Mission Viejo, CA, USA) was worn by each subject during data collection and used to transmit raw SEMG data via a fiber optic cable to its receiver unit. Unit specifications include an amplifier gain of 2000 Hz, an input impedance of 1 MΩ, and a CMRR of 90 dB. Muscle activation of the involved and uninvolved limb gluteus medius muscles was collected for each subject using bi-polar Ag–AgCl surface electrodes (Ambu Inc., Glen Burnie, MD, USA) measuring 5 mm in diameter with a center-to-center distance of 2.0 cm. The involved limb of the subjects with hip OA was defined as the limb which was undergoing surgery and was matched to the dominant limb of the control subjects, defined as the leg with which they would kick a ball. The skin was prepared, and electrodes were placed in parallel arrangement over the muscle belly for each muscle, as described by Cram et al. (1998). Electrode placement for both muscles was the proximal one-third of the distance between the highest point on the iliac crest and the greater trochanter of the femur. Electrodes were secured to the skin using Cover-Roll (Beiersdorf-Jobst, Charlotte, NC, USA). SEMG data were sampled at 1000 Hz and analyzed using Datapac software (Run Technologies, Mission Viejo, CA, USA). A foot switch was placed in the shoe of both lower extremities to determine foot contact and foot lift-off during the performance of the functional activities. Footswitch data was collected at 1000 Hz and synchronized with the SEMG data using the Datapac software.

Table 1
Subject demographics.

	n	Age (yr)	Height (cm)	Mass (kg)
CON	17	50.8 (1.4)	173.1 (2.5)	77.3 (3.8)
OA	13	51.1 (2.3)	178.2 (4.3)	84.2 (6.8)

Data are presented as mean (SEM).
CON = control group.
OA = hip osteoarthritis group.
yr = year.
cm = centimeters.
kg = kilograms.

Following electrode placement, subjects were asked to perform three maximum voluntary isometric contractions (MVICs) contractions. Each trial lasted 3 s with a 30-second break in between trials. The subjects with hip OA were unable to perform MVIC testing for the gluteus medius in the traditional side lying hip abduction position because of pain; therefore, MVIC data were collected for both groups during isometric weight-bearing hip abduction. Given that the primary function of this muscle is pelvic stabilization in the frontal plane (Gottschalk et al., 1989; Inman, 1947; Neumann, 2010; Ward et al., 2010), we believe the testing methods we employed were appropriate for acquiring maximal muscle activation. The subjects were allowed to practice the MVIC data collection methods until they felt confident in performing them. Subjects stood in front of a stationary pole with their feet shoulder width apart. Resistance to movement was provided by an immobilization strap placed around both ankles. Subjects were instructed to push out against the immobile strap, attempting to abduct their leg, as hard as they could for the entire 3-second trial. MVIC data was collected for the non-pushing limb during each trial. They were instructed to keep their toes pointed forward to primarily challenge the gluteal medius musculature and to avoid leaning to the side during each trial. Failure to do so resulted in the trial being discarded and repeated. They were allowed to maintain balance, but were instructed not to lean into the pole. This procedure was repeated for the other leg.

2.4. Force platform

Impact force data was collected using the 6 foot long force plate of the NeuroCom Smart Balance Master (NeuroCom Inc, Clackamas, OR, USA). The subjects performed step up, step down, and level gait. A member of the research team instructed each subject on the performance of each test on the long force plate. Following MVIC data collection, each subject performed each task, with a 30-second rest in between each trial and a 2 minute rest between exercises to prevent fatigue. Order of testing was randomized between subjects to prevent order bias, and subjects were allowed to practice the functional tasks until they felt confident in performing them.

2.4.1. Step tasks

Step up and step down were performed three times for each limb for a total of six trials at a controlled pace of 55 beats per minute in order to attempt to control velocity of movement (Brophy et al., 2010) (Fig. 1). For each trial, the subject stood on the force plate behind an 8-inch high box. All subjects performed the step tasks using the uninvolved limb first. For step up, subjects were instructed to step up onto the box using the uninvolved limb and then bring their involved limb up onto the box. For step down, subjects were instructed to step forward off the box onto the force plate, landing as softly as possible, leading with the involved limb, followed by the uninvolved limb, and come to