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Neuromuscular response of hip-spanning and low back muscles to medio-lateral foot center of pressure manipulation during gait

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A B S T R A C T

Background: Footwear-generated medio-lateral foot center of pressure manipulation has been shown to have potential positive effects on gait parameters of hip osteoarthritis patients, ultimately reducing maximum joint reaction forces. The objective of this study was to investigate effects of medio-lateral foot center of pressure manipulation on muscle activity of hip-spanning and back muscles during gait in bilateral hip osteoarthritis patients. *Methods:* Foot center of pressure was shifted along the medio-lateral foot axis using a foot-worn biomechanical device allowing controlled center of pressure manipulation. Sixteen female bilateral hip osteoarthritis patients underwent electromyography analysis while walking in the device set to three parasagittal configurations: neutral (control), medial, and lateral. Seven hip-spanning muscles (Gluteus Medius, Gluteus Maximus, Tensor Fascia Latae, Rectus Femoris, Semitendinosis, Biceps Femoris, Adductor Magnus) and one back muscle (Erector Spinae) were analyzed. Magnitude and temporal parameters were calculated. *Results:* The amplitude and temporal parameter varied significantly between foot center of pressure positions for 5 out of 8 muscles each for either the more or less symptomatic leg in at least one subphase of the gait cycle. *Conclusion:* Medio-lateral foot center of pressure manipulation significantly affects neuromuscular pattern of hip and back musculature during gait in female hip bilateral osteoarthritis patients.

1. Introduction

Hip osteoarthritis (OA) is a chronic, debilitating, painful, and progressive disorder affecting a large amount of the population and having a great economic burden. Symptomatic hip OA is estimated to have a prevalence of 9.2% (9.3 female, 8.7 male) for those over 45 years of age (Helmick et al., 2003). Radiological evidence can be detected in most people over the age of 55 (Kellgren and Lawrence, 1958). Cost of hospital expenditures for total hip replacements in 2009 was estimated at $13.7 billion (Murphy and Helmick, 2012).

Hip OA is associated with radiographic evidence of pathology in the joint and gait that significantly deviates from normal. The abnormal gait is accompanied by neuromuscular patterns that also deviate from those of healthy people (Sims et al., 2002). Specific descriptions of muscle activation patterns in bilateral hip OA are lacking in the literate. General neuromuscular abnormalities, however, are observed with hip OA, including muscle weakness and atrophy, due to disuse, pain, and joint dysfunction, causing potential joint instability, lack of support of the joint, and progression of OA (Garstang and Stitik, 2006; French et al., 2008). These gait changes may not only affect the pathological joint(s). Pathologically altered lumbar kinematics may lead to low back pain or lumbar dysfunction (Bejek et al., 2006; Watelain et al., 2001). Current clinical recommendations for the treatment of hip OA include reduction of load on the pathological joint(s) as well as muscle strengthening exercises (Zhang et al., 2008).

In our previous studies on the knee in both healthy and knee OA patients, it was shown that medio-lateral foot center of pressure (COP) manipulation decreases knee adduction moment and joint loads, known to play a major role in onset/progression of knee OA (Haim et al., 2008, 2011). This was associated with significant simultaneous effects on the neuromuscular pattern of lower-limb musculature (Goryachev et al., 2011a, 2011b). Recently, in a pilot study on healthy subjects, medio-lateral foot COP manipulation

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was shown to significantly affect hip kinetics and kinematics and ultimately reduce maximum hip joint reaction force during gait (Solomonow-Avnon et al., 2015). In a subsequent validation study in the same cohort of female bilateral hip OA patients as the present study, we observed the same significant changes in hip kinetics, kinematics, and joint reaction force in both the more symptomatic and less symptomatic limb (Solomonow-Avnon et al., 2016). Given the important potential clinical implications of this finding, the present study therefore investigated the simultaneous response of neuromuscular patterns in several hip-spanning muscles and one back muscle to provide a basis for further investigation of precise neuromuscular response patterns to COP manipulation.

The objective of this study was to investigate the impact of medio-lateral COP manipulation on neuromuscular patterns of the hip and back musculature. Specifically, we wished to investigate which of these muscles, of both the more symptomatic and less symptomatic limb, are able to be influenced by frontal-plane COP modulation. We hypothesized that medio-lateral COP manipulation would have a direct significant influence on electromyography (EMG) patterns of the hip-spanning and back muscles during various phases of the gait cycle.

2. Methods

2.1. Participants

Sixteen females with bilateral hip OA (Age = 63.5 ± 6.3 yrs, Height = 159.7 ± 5.6 cm, Body mass = 73.3 ± 17.5 kg, Kellgren–Lawrence grade for more symptomatic leg = 2.93 ± 0.46, Kellgren–Lawrence grade for less symptomatic leg = 2.6 ± 0.63) were recruited from a cohort of patients enrolled in a clinical trial in the Department of Orthopedics at Rambam Medical Center, Haifa, Israel and Ha'Emek Medical Center, Afula, Israel, investigating the longitudinal effects of biomechanical training with COP modulation on gait and EMG parameters. Data for the present study was collected before initiation of the clinical trial. All patients had symptomatic bilateral hip OA according to the American College of Rheumatology criteria for hip OA, with radiographic evidence of Kellgren–Lawrence grades 2–4 (Altman et al., 1991; Kellgren and Lawrence, 1957). All patients had a more symptomatic joint, which was indicated by the patients at the start of the study. Exclusion criteria were any orthopedic, musculoskeletal, or neurological pathology, previous surgery of the back and lower limbs, any other co-morbidities affecting the back and lower limbs and gait, and use of a walking aid. Approval of the Ethics Sub-Committee was obtained and informed consent was given by all participants. The purpose and methods of the study were explained to the subjects.

2.2. The biomechanical system

The APOS biomechanical device (APOS System, APOS—Medical and Sports Technologies Ltd. Herzliya, Israel) was used and was previously described in detail (Haim et al., 2008). In brief, COP manipulation is accomplished using a platform in the form of a shoe in which two adjustable convex-shaped biomechanical elements are attached to the feet by means of a shoe sole specially designed with two mounting rails (Fig. 1(a)).

2.3. Experimental protocol

The experimental protocol used in the study is consistent with that outlined in detail in our previous studies using the biomechanical device (Goryachev et al., 2011a, 2011b). The functional neutral configuration (FNC) was custom-defined and documented by a single trained physiotherapist (Haim et al., 2008). The FNC was defined for each subject as the position of the elements in which the least varus, valgus, plantar, and dorsal torque was exerted by the apparatus about the ankle. The medial and lateral COP configurations were defined as 0.8-cm medial and 1.5-cm lateral deviations, respectively, of the biomechanical elements from the neutral sagittal axis (line connecting centers of biomechanical elements in the FNC) (Fig. 1(b–d)).

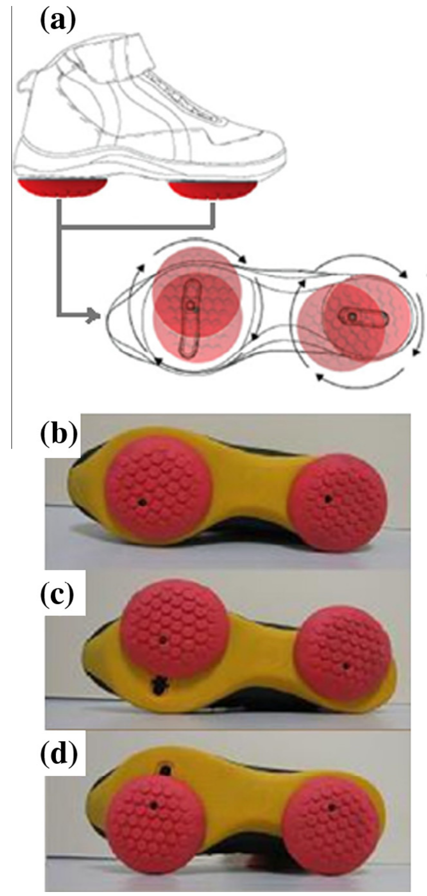

Fig. 1. (a) Biomechanical device with adjustable elements in (b) neutral, (c) lateral, and (d) medial configurations.

Subjects were given a several-minute period prior to data acquisition to walk at a comfortable self-selected speed in the biomechanical device in order to become accustomed. After the accustomization period, EMG data were acquired simultaneously with kinetic and kinematic data, used in another study (Solomonow-Avnon et al., 2016), using Vicon Nexus software (Oxford Metrics Ltd., Oxford UK). Data were recorded while subjects walked over a 10-m walkway at their comfortable self-selected speed in the three COP conditions – medial (M), neutral (N), and lateral (L) – at random order on the same day. Six to ten walking trials were performed in each COP condition.

2.4. Data acquisition and processing

A Surface EMG ZeroWire system (Aurion Ltd., Italy) was used to measure the activity of the following muscles bilaterally: gluteus medius (GMed), gluteus maximus (GMax), tensor fascia latae (TFL), rectus femoris (RF), semitendinosus (ST), biceps femoris (BF), erector spinae (ES), and adductor magnus (AM). Wireless surface electrodes were attached comfortably to the patients' skin.