Gait & Posture 50 (2016) 201–206

Contents lists available at ScienceDirect

Gait & Posture

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

The effects of acute experimental hip muscle pain on dynamic single-limb balance performance in healthy middle-aged adults

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ARTICLE INFO

Article history:
Received 26 February 2016
Received in revised form 5 September 2016
Accepted 8 September 2016

Keywords:
Hip muscle pain
Hypertonic saline
Balance performance
Middle-aged adults

ABSTRACT

Middle-aged adults with painful hip conditions show balance impairments that are consistent with an increased risk of falls. Pathological changes at the hip, accompanied by pain, may accelerate pre-existing age-related balance deficits present in midlife. To consider the influence of pain alone, we investigated the effects of acute experimental hip muscle pain on dynamic single-limb balance in middle-aged adults. Thirty-four healthy adults aged 40–60 years formed two groups (*Group-1:* n = 16; *Group-2*: n = 18). Participants performed four tasks: Reactive Sideways Stepping (ReactSide); Star Excursion Balance Test (SEBT); Step Test; Single-Limb Squat; before and after an injection of hypertonic saline into the right gluteus medius muscle (*Group-1*) or ~5 min rest (*Group-2*). Balance measures included the range and standard deviation of centre of pressure (CoP) movement in mediolateral and anterior-posterior directions, and CoP total path velocity (ReactSide, Squat); reach distance (SEBT); and number of completed steps (Step Test). Data were assessed using three-way analysis of variance. Motor outcomes were altered during the second repetition of tasks irrespective of exposure to experimental hip muscle pain or rest, with reduced SEBT anterior reach (-1.2 ± 4.1 cm, $P = 0.027$); greater step number during Step Test (1.5 ± 1.7 steps, $P < 0.001$); and slower CoP velocity during Single-Limb Squat ($-4.9 \pm 9.4\,\text{mms}^{-1}$, $P = 0.024$). Factors other than the presence of pain may play a greater role in balance impairments in middle-aged adults with hip pathologies.

1. Introduction

Age-related balance impairments are observed in adults from as early as their fourth decade [1]. For example, healthy women aged 40–80 years have reduced single-limb balance control during quiet standing [2,3], lower limb reaching [4], and stepping [3] tasks, compared to younger adults. Decreased lower limb muscle strength [5,6], reduced joint range of motion [6,7], altered sensorimotor function [8,9], and declining physical activity levels [6,7,10], may all contribute to balance deficits in midlife.

At the hip, greater trochanteric pain syndrome, chondropathy, and osteoarthritis are common sources of hip pain. Chronic pain is of particular concern in middle-aged adults, as it appears to be a strong risk factor for falls in later life [11,12]. Consistent with an increased risk of falling, dynamic single-limb balance is impaired in adults who show early signs of hip joint degeneration and report mild pain [13]. Further, the presence of hip osteoarthritis is associated with delayed postural adjustments prior to rapid sideways stepping [14], and impaired recovery of balance following perturbation [15]. Therefore, the presence of painful musculoskeletal disease or injury could accelerate pre-existing age-related balance deficits.

Pain is a modifiable patient-reported outcome with appropriate management. Greater understanding of how hip muscle pain alone, without the presence of pathology, can affect balance in middle-aged adults may inform the development of more effective strategies to manage balance problems in this population. Therefore, the aim of this study was to investigate the effects of hip muscle pain on dynamic balance in healthy middle-aged

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http://dx.doi.org/10.1016/j.gaitpost.2016.09.007
0966-6362/

adults. We hypothesised that hip pain would lead to a deterioration of motor performance, that is, greater centre of pressure (CoP) movement during reactive side-stepping and single-limb squat tasks; reduced reach distance during the Star Excursion Balance Test (SEBT) and; fewer steps taken during the Step Test; relative to a no pain (control) condition. To isolate the effect of nociceptive stimulation from structural impairments, pain was induced experimentally by injection of hypertonic saline. At the hip, injections of hypertonic saline into gluteus medius have led to patterns of referred pain, regional deep tissue hyperalgesia, and pain provocation test responses, similar to those observed in hip pathologies [16]. We used a within-subject repeated measures design with two groups. Group-1 performed balance tasks before and after induced hip pain. Group-2 performed the tasks twice, with no pain. This design also allowed us to determine whether performance of novel motor tasks improves with repetition in middle-aged adults. We hypothesised that performance would improve in Group-2 (consistent with short-term adaptions in motor performance with repetition [17]), but that the presence of pain would be associated with worse performance in Group-1.

2. Methods

2.1. Participants

Thirty-four healthy adults aged 40–60 years, were included in the study. Of these, 16 adults (11 women, 5 men; age 50.5 ± 3.4 years; height 1.70 ± 0.09m; weight 71.1 ± 16.6 kg) formed Group-1; and 18 adults (16 women, 2 men; age 51.6 ± 4.6 years; height 1.67 ± 0.08m; weight 63.6 ± 12.0 kg) formed Group-2. Group allocation was based on the participant's willingness to receive an injection of hypertonic saline into their hip muscle and experience acute pain.

Exclusion criteria for both groups included current back or lower limb injuries or disease including pain; symptomatic hip or knee osteoarthritis; hip surgery; neurological conditions or previous stroke, sensory conditions known to alter balance (e.g. peripheral neuropathy); current use of pain medication or; inability to read/speak English. The study was approved by the Institutional Medical Research Ethics Committee (#2004000654). All procedures conformed to the Declaration of Helsinki. Written informed consent was obtained from all participants.

2.2. Design

Group-1 and Group-2 refer to the *Pain* and *Control* portions of this study, respectively. The protocols do not differ between Groups (except for the inclusion of a pain stimulus in Group-1). All participants conducted two blocks of testing, one before (Block-1) and one after (Block-2) the administration of acute pain (Group-1) or ~5 min rest (Group-2). The balance tasks included: Reactive Sideways Stepping (ReactSide); SEBT; Step Test; and Single-Limb Squats.

2.3. Equipment

Force data were obtained using two Kistler force platforms (Model 9296AA, Kistler, Alton, UK), sampled at 100 Hz (Power1401 Data Acquisition System, Cambridge Electronic Design, UK) and low-pass filtered (20 Hz, 4th order Butterworth filter) offline. An electrogoniometer (Twin Axis SG150, Biometrics Ltd., Newport, UK) was attached laterally over each knee joint, and used to measure knee angle during the squat. Data were sampled at 40 Hz (DataLINK DLK900, Biometrics Ltd., Newport, UK). All data were collected using Spike 2 software (Cambridge Electronic Design, UK).

2.4. Balance tasks

Participants were barefoot, with their eyes open and arms folded across their chest for all tasks. Prior to data collection, the investigator demonstrated each task, and participants performed 1–2 practice trials to facilitate familiarity with the procedures. For each task, the initial test leg was randomised. During Block-2, fewer trials were performed, in an attempt to complete all tasks before the cessation of pain (in Group-1, and for consistency, the number of repeats were matched in Group-2). For all tasks, balance measures were averaged across repetitions.

2.5. Reactive sideways stepping

Participants adopted a double-limb standing position, with one foot on each force platform, and their bodyweight evenly distributed between both legs. Taped lines were placed 10 cm and 20 cm lateral to the fifth metatarsal head of each foot [14]. In response to a verbal cue, participants stepped ~15 cm sideways (to place their foot between the taped lines), as quickly as possible. The final position was maintained for ~3s, before returning to the starting position (Fig. 1). Participants completed 20 trials (10 per leg), randomly presented. Approximately 10 s was given between trials to allow for repositioning and rest. During Block-2, participants performed 5 trials per leg.

2.6. Star excursion balance test

An 8-point star (each point set at 45°) was taped on the floor [18]. Participants began with the heel of their test leg at the centre of the star. Participants were instructed to "*Reach as far as possible along the line, without moving your standing foot. Keep the heel of your standing foot down. When touching the line with your reaching foot, try not to step or place all your weight down: lightly touch the ground then return to the starting position*." Participants performed three reaches along the anterior, medial and posteromedial lines. A 10 s rest period was provided between repetitions. Tests were discarded and repeated if a participant raised the heel of their test leg off the ground, lost their balance, or bore weight through their reaching leg. The distance reached in each direction, per repetition, was measured. During Block-2, participants performed 1 reach per leg in all three directions.

2.7. Step test

Whilst in a comfortable, double-limb standing position, a taped line was placed horizontally, in front of the most distal aspect of the participant's hallux. A 15 cm high step (80 cm width × 60 cm depth) was placed 5 cm in front of the taped line. Participants were instructed to "*Place your full foot on and off the step as many times as possible in 15s, keeping your other foot on the force platform*." [19]. The Step Test was performed three times on each leg, with a 5 s rest period between trials. During Block-2, the Step Test was performed once on each leg. The number of completed steps performed in 15 s was recorded.

2.8. Single-limb squat

An electrogoniometer was taped to the lateral aspect of each leg, across the knee joint. Thereafter, a plinth was placed directly behind the participant, with the height adjusted so that upon reaching an angle of 60° knee flexion, the participants' buttocks lightly touched the plinth [13,20]. Participants stood with their test leg on a force platform, and were instructed to *'squat down until your buttocks lightly touch the bed behind, then return to the starting position and repeat 3 times in time with the count'* (Fig. 2). For each