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Hip abductor muscle volume in hip osteoarthritis and matched controls

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SUMMARY

Objective: Hip abductor muscle strength and function is negatively impacted by the presence of hip osteoarthritis (OA). This study aimed to quantify differences in hip abductor muscle volume, fatty infiltration and strength in a unilateral hip OA population when compared to a control group. Impact of radiographic severity of OA on these variables was also examined.
Methods: Volumes of gluteus maximus (GMax), medius (GMed) minimus (GMin) and tensor fascia lata (TFL) was measured using MRI and muscle volume asymmetry between limbs was calculated. Fatty infiltrate within muscles was graded using the Goutallier classification system. Hip abduction and rotation strength was tested using a dynamometer. Differences between groups or limbs were analysed using *t*-tests and differences in fatty infiltration using non-parametric tests.
Results: A statistically significant decrease in muscle volume was identified in GMax ($P < 0.01$), GMed ($P < 0.02$) and GMin ($P < 0.01$) on the affected side in the OA group compared to both the contralateral side and the control group and differences were related to severity of OA. Hip abduction and internal rotation strength was reduced in the OA group. Increased levels of fatty infiltration were identified in the affected limbs of the OA group for GMax ($P = 0.01$) and GMin ($P = 0.04$).
Conclusion: Gluteal muscle atrophy, increased gluteal fatty infiltration and hip strength deficits were evident in the affected hips of OA participants. Since severity of OA was related to the extent of atrophy and fatty deposits, rehabilitation programs targeting these muscles could reverse or halt the progression of these structural and functional deficits.

Introduction

Osteoarthritis (OA) affects 26% of females and 16% of males aged over 55 years old in Australia[1] and primarily affects weight bearing joints such as the hip and knee. Muscular weakness, joint pain and reduced ambulatory capacity are characteristic of patients with lower limb OA[2]. Atrophy of the muscles around the affected joint has been identified in OA[3] and muscle weakness can be a predictor for the presence of asymptomatic OA[4]. There are suggestions that muscle weakness could be a primary risk factor for OA[5] and atrophy or weakness of the periarticular muscles has been implicated in the development, progression and severity of OA[6]. Considering these findings and perceptions, there has been interest in the activation, size, strength and function of the deep hip stabilising muscles in the presence of hip OA[7].

The gluteus medius (GMed) and minimus (GMin) function as hip abductors and are considered to be the major stabilisers at the hip joint[8]. Hip abductor strength deficits are commonly seen in hip OA patients[9]. Weakness in muscle can be manifested as either a reduction in muscle size or muscle activity[10]. While strength deficits have been identified in hip OA populations when compared to a control, muscle volume (or size) has not been shown to differ between OA patients and controls in a systematic review[9]. Although, there is preliminary evidence to suggest that atrophy of these muscles may only be evident in advanced OA[11].

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It is logical that deep hip muscle volume changes exist in OA given the consistent strength deficits identified in this population[9]. The amount of force that can be produced by a muscle is directly proportional to its cross-sectional area (CSA)[12]. However, the total CSA of a given muscle is a measure of both contractile and non-contractile tissue[13] and in muscle atrophy, fatty tissue occupies the space left behind by degenerating muscle fibres[14]. Muscle function can be influenced by the amount of fatty infiltration[15] so it is important to exclude all non-contractile tissue while analysing the total CSA of muscle. This has not been performed to date in studies of hip OA populations.

Therefore the aim of this study was to quantify gluteal muscle atrophy in hip OA patients by comparison of muscle volume with an age- and gender-matched control group. Secondary aims of this study were to relate atrophy of these muscles to severity of OA, and to compare levels of fatty infiltration and hip strength between OA and control groups.

Methods

Participants

Forty participants were included in the study; 20 with unilateral hip OA and 20 age- and gender-matched control participants. Participants were included in the OA cohort if they had radiologically confirmed unilateral hip OA of at least Grade 2[16], were able to walk unaided and scored <40 on the Oxford Hip Score[17] indicating moderate to severe levels of disability. Control group participants were age-matched (±5 yrs) with no radiological evidence of hip OA and scored >40 on the Oxford Hip Score. Participants were excluded from the study if they had contraindications to magnetic resonance imaging (MRI) scanning techniques (e.g., pacemaker, pregnancy or claustrophobia), and other medical, physical or neurological conditions that could lead to changes in the hip abductor muscle.

Unilateral hip OA patients meeting inclusion criteria were identified by a primary practitioner from the Osteoarthritis, Hip and Knee Service at the local hospital or other medical and physiotherapy practices. Control participants were recruited from the local community via advertisements in the local media and were screened for eligibility using inclusion criteria by the primary researcher. The study was approved by the Human Ethics Committee of the University and the local health network (HREC/12/BHCG/40).

Participant characteristics

Demographic data collected included age, weight and height. Hip-related disability was measured using the Oxford Hip Score, a patient-reported outcome measure that has been shown to have good test–retest reliability (ICC (2,1) = 0.89)[18]. Self-reported physical activity was assessed by calculating the activity metabolic index (AMI) using the Minnesota Leisure Time Physical Activity Questionnaire which has been shown to have high test–retest reliability for total activity (r_s = 0.79–0.88) and for subcategories of activity intensity (r_s = 0.69–0.86)[19].

MRI procedure

To control for limb dominance between groups, the muscle volume of the affected limb for each OA participant was compared with the same limb (stance or skill)[20] in the matched control participant. The tested limb in both groups has been referred to as the affected limb. Participants were screened for contraindication to MRI procedures by the MRI technician. Participants were imaged in a supine position with both feet secured to avoid any hip rotation. A Philips Achieve 3.0 Tesla scanner (SENSE XL Torso Coil 16 channel) was used for the MRI procedures. MultiTransmit was used to combat dielectric shading and coil inhomogeneity was corrected by using CLEAR (Philips homogeneity correction algorithm) at the time of image acquisition. A multi-planar localiser scan was performed from above the iliac crest to mid femur to identify the muscles of interest (particularly to be distal to insertion of tensor fascia lata (TFL)). A coronal T1 fast spin echo was then performed to include the region of interest. This was followed by an axial T1 fast spin echo that was acquired as a single stack. Two NSA (number of sample averages) were used for both sequences. The scanning parameters for the axial images were: Field of view = 290 mm × 400 mm, 56 slices of 6 mm slice thickness with 0 mm inter slice gap, repetition time = 715 milliseconds (ms), echo time = 7.1 ms, Voxel size = 0.39 × 0.39 × 6.0 mm.

Muscle volume measurements

Tracings of the gluteus maximus (GMax), GMed, GMin and TFL were performed using Sante DICOM editor software (Santesoft, Athens, Greece). The area of muscle on each slice was calculated by manually tracing individual muscle fascial outlines[11,21]. Any fatty infiltration of the muscle was excluded from the tracings to obtain a measure of only muscle tissue (Fig. 1). The final muscle volume for each muscle was calculated by the summation of the CSA of each muscle and multiplying it by the slice thickness (6 mm). Two assessors independently analysed the muscle volume and fatty infiltrate on both affected and unaffected limbs of five participants to allow the examination of inter-rater reliability.

Rating of fatty infiltration

Rating of the extent of fatty infiltration was conducted for the OA and control group on three consecutive slices using the Goutallier classification system[22]. This system allows classification of infiltration on a rating of 0–4 with; 0 being completely normal muscle, (1) the muscle contains some fatty streaks, (2) fatty infiltration is present but there is more muscle tissue than fat, (3) there are equal amounts of fat and muscle and, (4) being indicative of more fat than muscle[22]. The slices analysed for fatty infiltration for GMax, GMed and GMin were centred at the level of the superior aspect of the greater sciatic foramen and one immediately above and below [23]. The largest part of the TFL muscle belly is situated more inferiorly, and therefore the middle slice for the TFL was at the level of the fovea of head of femur and the two other slices immediately above and below. The average of the Goutallier scores across the three sections indicated the level of fatty infiltration for each muscle[22].

Strength measurement

Hip abduction, internal and external rotation strength was measured using a hand held dynamometer (Lafayette manual muscle test system, Lafayette, IN). The testing protocol was based on techniques used in previous studies[24]. Hip abduction strength was measured in the side lying position and rotation strength was measured with the participant in a sitting position. Resistance was applied just above the malleolus with the participant exerting a 3s isometric maximum voluntary contraction (MVC) against the resistance[24]. Verbal encouragement was given to the participant during each activity. Three trials of each activity was performed and the maximum value from the three trials was used for analysis.

Data analysis

All statistical analysis was completed using IBM SPSS program (Version 22, Chicago, IL USA). Muscle strength was normalized to