The Knee 23 (2016) 63–69

Contents lists available at ScienceDirect

The Knee

The effectiveness of an exercise programme on knee loading, muscle co-contraction, and pain in patients with medial knee osteoarthritis: A pilot study

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ARTICLE INFO

Article history:
Received 10 September 2014
Received in revised form 29 March 2015
Accepted 31 March 2015

Keywords:
Exercise
Osteoarthritis
Loading
Co-contraction

ABSTRACT

Background: Osteoarthritis (OA), which increases knee loading, muscle co-contraction, and pain, is a mechanical disease that requires biomechanical exploration to reduce pain in the knee. Therefore, this article aims to investigate the effectiveness of an exercise programme on the aforementioned outcomes in people with medial knee OA.

Methods: Cohort pilot study design. A total of 19 patients with knee OA attended a six-week group exercise programme integrated with self-management education. The following outcomes were assessed before and after the exercise programme: external knee adduction moment (EKAM), knee adduction angular impulse (KAAI), knee antagonist muscle co-contraction, and pain subscale of the knee injury and osteoarthritis outcome score (KOOS).

Results: Of the 19 patients, 14 completed the study. The EKAM and KAAI did not show statistical significance post-exercise intervention ($p = 0.21$-0.7 and 0.56, respectively). Muscle co-contraction between vastus lateralis and biceps femoris muscles decreased in early-stance (64.78 (44.35) compared with 38.10 (23.10), $p = 0.01$) and mid-stance (27.62 (32.12) compared with 14.94 (17.40), $p = 0.04$). A corresponding significant pain reduction was observed ($p = 0.00$) with a median (range) of 51.50 (47.00 to 62.50) at week 6 compared with 34.50 (29.25 to 41.25) at baseline.

Conclusion: This is the first known study to explore the effect of an exercise programme on knee loading and muscle co-contraction in patients with OA. Although the value of EKAM did not change, the findings suggest that the reduction in vastus lateralis and biceps femoris co-contraction might be the mechanism behind the reduction of pain.

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1. Introduction

Medial knee osteoarthritis (OA) is more common than lateral knee OA [1] because of the pattern of loading on the knee joint [2]. This is determined by the magnitude of the external knee adduction moment (EKAM) [3], which is the torque generated when the tibia rotates medially with respect to the femur in the frontal plane, and is a measure of the extent of varus deformity. Knee loading is also evaluated by the knee adduction angular impulse (KAAI) during gait, which considers the temporal variable throughout the stance phase (area under the curve) and not the peaks only at certain points [4].

The EKAM is associated with pain, disease progression, and severity of OA [5,6]. However, recent reports suggest that a mere reduction of the EKAM does not reduce the medial compressive forces acting throughout the knee and that coordination of the musculature around the knee (the co-contraction) should also be considered as knee antagonist muscle co-contraction is increased in knee OA compared with healthy individuals [7,8]. This increased co-contraction corresponds to a more generalised muscle activity, whereas lower co-contraction indicated more selective activation [9]. However, this increase might be a protective mechanism to improve knee joint stability during gait in the presence of muscle weakness with knee OA [10]. Knee stability is required during mid-stance when the 'screw home mechanism' activates the biceps femoris (BF) to externally rotate the tibia and achieve full knee extension [11]. In addition, this increase in co-contraction between the knee flexors and extensors together with the reduced range of flexion/extension movement observed in knee OA would concentrate loading on a small area of the joint, thereby exacerbating the symptoms.

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http://dx.doi.org/10.1016/j.knee.2015.03.014
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However, the relationships between muscle co-contraction, knee joint loading, pain, and strength during gait, and the effectiveness of interventions on co-contraction are unknown.

Exercise is known to improve pain, function, and strength in patients with knee OA [12,13], and several studies have investigated the effect of open kinetic chain (OKC) exercises strengthening the knee or hip muscles of the patients on the EKAM [13–17]. The results of these studies have shown that strengthening the knee flexors and extensors or hip abductors did not significantly change the EKAM [13–16], but did improve pain, function, and strength, thus validating the purpose of its proposal [18].

It is worth noting that these OKC exercises were used in these studies and that including closed kinetic chain (CKC) exercises may be more effective in decreasing the EKAM as, when performed slowly, they require the co-contraction of agonist and antagonist muscles (i.e. the quadriceps and hamstring) to stabilise the knee joint [19], and are considered more closely related to the movements and forces produced to perform everyday functional tasks. Two small studies have explored the effect of CKC exercises on knee joint loading in patients with knee OA, with varying results [20,21].

CKC exercises may have an effect on muscle co-contraction during gait in knee OA. To date, only McQuade and de Oliveira [22] have explored the effect of an eight week progressive resistive exercise programme of the knee flexors and extensors on muscle co-contraction and the EKAM, both of which were estimated during step-ups, and the former was assessed using hamstring/quadriceps electromyography (EMG) activity ratio. Neither the EKAM nor the muscle co-contraction significantly changed. The purpose of this study was to examine the effect of a strengthening exercise programme, involving OKC and CKC exercises of the hip and knee muscles, on knee loading, antagonist muscle co-contraction, pain, and muscle strength in patients with medial knee OA.

To the best of our knowledge, this is the first study to investigate the effect of exercise on antagonist muscle co-contraction in patients with medial knee OA. The primary hypothesis of this pilot study was that the exercise programme would reduce knee joint loading during gait. The secondary hypothesis suggested that the exercise programme would reduce the increased knee antagonist muscle co-contraction. The third hypothesis was that a reduction in muscle co-contraction would reduce knee joint loading. Precisely, the exercise programme would decrease pain and improve muscle strength.

2. Material and methods

A pilot cohort design was used to examine the immediate effects of a six week exercise programme. Ethical approval of the study was obtained from the North West Research Ethics Committee and University Research and Governance Ethics Committee, and informed written consent was obtained from each participant.

2.1. Participants

Participants with predominantly medial knee OA, who have met the clinical and/or radiological criteria of the American College of Rheumatology (ACR) for knee OA [23], were selected by a member of the physiotherapy team at a local hospital, who invited only valid participants on the basis of either their clinical assessment or radiographic reports from a musculoskeletal radiologist confirming medial knee OA. Among them, only interested participants were contacted by the lead author, who further clinically assessed if they met the inclusion criteria. Patients who had previous knee realignment surgery, gross ligament instability, and patellofemoral or lateral knee OA exceeding medial stage radiographically and clinically; any other condition that limited mobility or the everyday activities; been injected corticosteroid in the knee in the last three months, or took other medication that may limit participation in the exercise programme and/or assessments; wore or used an assistive device to help mobility; or participated in other treatment (exercise) programmes that could affect the results of this study were excluded.

2.2. Assessment procedure

Demographic data of all participants were recorded (age, gender, weight, and height). In order to progress the participants' exercise regimen, an initial weight assessment was done in the first session only, where each participant was made to hold a weight (dumb-bell) with both hands and do one bilateral squat. They were enquired about the task difficulty and the weight was increased accordingly until the maximum weight they could hold whilst squatting was reached, which is referred to as their 1RM (repetition maximum). Then, 75% of the 1RM was used to determine their 10RM [24] for future purpose.

Outcomes were assessed before the start of the six week exercise programme and within one week after its end.

2.2.1. Gait kinematics and kinetics

Kinematic data were collected using a 16-camera Oqus computerised motion analysis system at 100 Hz (Qualisys, Gothenburg, Sweden). Kinetic data were collected using two force platforms at 200 Hz (model BP400600, Advanced Mechanical Technology, Inc (AMTI), Watertown, MA, USA).

Retroreflective markers were attached bilaterally to bony areas (anatomical markers) using a hypo-allergenic adhesive tape, when the participant was in standing position. These were located at the ankles (medial and lateral malleoli), knees (medial and lateral femoral epicondyles), thighs (right and left greater trochanters), pelvis (anterior superior iliac spines, posterior superior iliac spines, and iliac crests), and shoulders (right and left acromial processes). The CAST protocol [25] was used to track segmental kinematics in six degrees of freedom (DOF). Rigid cluster pads, made of plastic with four markers on each, were attached to the shank, thigh, pelvis, and sternal notch using Fabrifoam SuperWrap bandages to ensure no movement of these plates down the limbs.

The participants were made familiar with the testing procedure by performing several walking trials to achieve a steady walking speed. This was followed by five successful trials at a self-selected walking speed, because an increase in speed would increase the ground reaction force (GRF), which will in turn increase knee joint loading and misinterpret the result of the exercise programme [26]. Post-processing kinematic and kinetic data were calculated using Visual3D software (C-Motion Inc., Rockville, MD, USA). All lower extremity segments were modelled as rigid bodies. Anatomical frames were defined by areas positioned at the medial and lateral borders of the joint. From these, right-handed segment coordinate systems were defined. Joint kinematics data were calculated using an X–Y–Z Euler rotation sequence equivalent to the joint coordinate system [27], whereas joint kinetic data were calculated using three-dimensional inverse dynamics and the external joint moment data were normalised to body mass (Nm/Kg). The biomechanical parameters assessed were: peak EKAM during early-, mid-, and late-stances, KAAI throughout the stance phase [4], and peak knee flexion and extension moments on the affected side only.

2.2.2. Co-contraction

Surface EMG data were collected using the TELEmyo system (Noraxon, USA) at a sampling rate of 3000 Hz. A total of eight channels were used to record the average activation with electrodes placed on the right and left vastus lateralis (VL), vastus medialis (VM), BF, and semitendinosus (ST) muscles. The ground electrode was placed on the patella, and the electrodes were bipolar, disposable, self-adhesive, silver/silver chlorine, and pre-gelled (Noraxon Dual Electrodes™). These were placed parallel to muscle fibres with an inter-electrode distance of at least two centimetres. Skin

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