Gait & Posture 57 (2017) 246–251

Contents lists available at ScienceDirect

Gait & Posture

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

Full length article

Gait adaptations with aging in healthy participants and people with knee-joint osteoarthritis

Lynsey D. Duffell[a,b,*], Stevan J. Jordan[b], Justin P. Cobb[b], Alison H. McGregor[b]

[a] Dept of Medical Physics and Biomedical Engineering, UCL, UK
[b] MSK Lab, Imperial College London, UK

ARTICLE INFO

Keywords:
Aging
Gait
Knee
Osteoarthritis

ABSTRACT

The relationship between age and gait characteristics in people with and without medial compartment osteoarthritis (OA) remains unclear. We aimed to characterize this relationship and to relate biomechanical and structural parameters in a subset of OA patients. Twenty five participants with diagnosed unilateral medial knee OA and 84 healthy participants, with no known knee pathology were recruited. 3D motion capture was used to analyse sagittal and coronal plane gait parameters while participants walked at a comfortable speed. Participants were categorized according to age (18–30, 31–59 and 60+ years), and those with and without OA were compared between and within age groups. In a subset of OA patients, clinically available Computed Tomography images were used to assess joint structure. Differences in coronal plane kinematics at the hip and knee were noted in participants with OA particularly those who were older compared with our healthy controls, as well as increased knee moments. Knee adduction moment correlated with structural parameters in the subset of OA patients. Increased knee moments and altered kinematics were observed in older participants presenting with OA only, which seem to be related to morphological changes in the joint due to OA, as opposed to being related to the initial cause of medial knee OA.

1. Introduction

Knee joint osteoarthritis (OA) is one of the commonest diseases affecting the aging population, so there is a growing interest in the mechanisms underlying this degenerative disease. The progression of knee OA has been related to gait mechanics [1], specifically relating to tempo-spatial parameters [2]. However, this can be complex since gait adaptations that occur in normal aging can be similar to those seen in pathological participants. A better understanding of normal and pathological aging would assist in the management of OA, if disease development or progression is directly related to certain characteristics of gait.

The development of medial knee OA has been postulated to result from repetitive loading, leading to meniscal fatigue failure or acute injury, with subsequent medial compartment articular cartilage loss. This is supported by reports that OA incidence significantly increases with age [3,4], as well as evidence indicating that its incidence is associated with obesity, knee trauma and female gender [4]. In addition, an increase in external knee adduction moment (KAM), which is associated with increased medial knee-joint forces, has been reported in people with moderate to severe medial knee OA [5–7], and has been correlated with disease progression [8] and severity [9–11]. However, there is little evidence supporting the presence of higher KAMs in the early stages of knee OA [2,11–13], indicating higher medial loads may not be causative of medial knee OA. Recent studies have suggested that KAM can be influenced by trunk motion [14]. People with knee OA demonstrate significant hip muscle weakness [15], which has been suggested to be a risk factor in the development of knee OA [16] due to pelvic drop increasing KAM magnitude [17]. Others however have proposed that hip abductor strength has little influence on hip and knee adduction moments during gait [18,19].

Changes in gait mechanics with healthy aging include decreased stride length and increased cadence [20,21], and associated alterations in sagittal plane hip and ankle kinematics and kinetics [20–22]. Altered knee flexion range of motion has also been proposed in healthy aging [22–24], but changes in the coronal plane are less well understood. A slight increase in valgus static alignment has reported [25] as well as increased abduction during early stance in gait [24]. Reduced medial knee-joint forces with advancing age have also been reported [22]. The association between aging, biomechanical loading, structural joint changes and OA development warrants further investigation, in particular coronal plane biomechanics due to their implication in knee OA.

* Corresponding author at: Dept of Medical Physics and Biomedical Engineering, University College London, Malet Place Engineering Building, Gower Street, London, WC1E 6BT, UK.
E-mail address: l.duffell@ucl.ac.uk (L.D. Duffell).

http://dx.doi.org/10.1016/j.gaitpost.2017.06.015
Received 11 December 2015; Received in revised form 10 April 2017; Accepted 20 June 2017
0966-6362/

The aim of this study was to demonstrate the relationship between age and gait characteristics in people with and without medial compartment OA. Gait and structural parameters at the knee joint were also investigated in a subset of OA patients. We hypothesized that; i) younger OA subjects would have similar KAMs as healthy subjects; ii) older healthy subjects would have altered gait mechanics compared with young healthy subjects and; iii) older OA subjects would show deviations in gait parameters compared with healthy young and older subjects.

2. Methodology

This study had ethical approval from the South West London Research Ethics Committee and all participants provided written informed consent. Twenty-five participants with a clinical diagnosis of unilateral knee OA affecting the medial compartment were recruited from Charing Cross Hospital and local district regional hospitals, and 84 participants with no known knee pathology were recruited from staff and students of Imperial College London. Participants were excluded from the study if they demonstrated any neurological or musculoskeletal condition other than knee OA, rheumatoid or other systemic inflammatory arthritis, morbid obesity (Body Mass Index > 35 kg/m^2) or had undergone previous surgical treatment for knee OA.

2.1. Gait analysis

Two Kistler portable force plates (Kistler Type 9286B, Kistler Instrumente AG, Winterthur, Switzerland) were embedded into a 6 m walkway, and a 10 camera Vicon motion capture system (Vicon Motion Systems Ltd, Oxford, UK) were used to capture the position of reflective markers attached to the subject. Force plate data were recorded using an analogue signal data acquisition card provided with the Vicon system and the Vicon Nexus software at a sampling rate of 1000 Hz. The motion capture was recorded at a rate of 100 Hz and synchronised with the force data.

Twenty reflective markers were positioned on the subject's pelvis and lower limbs and four marker clusters positioned on the subject's left and right thigh and calf segments [26]. Participants were asked to walk at a comfortable speed along the 6 m walkway 5 times, or until three clean foot strikes had been recorded from each force plate.

Kinematic and kinetic parameters were calculated using a custom model written in body builder software [26]. Joint moments were normalised to the subject's bodyweight x height. Data was separated into gait cycles for each leg based on vertical ground reaction forces and time-normalised. Hip, knee and ankle joint angles at heel strike (HS), toe-off (TO) and the time point at which 1st peak vertical ground reaction force (GRF) occurred were extracted using custom written code in Matlab. Only joint moments at 1st peak GRF were extracted. The average of three trials was taken.

2.2. Sub-group computed tomography analysis

A subset of 6 of the OA participants additionally underwent preoperative CT scans of their affected knee using the Imperial knee protocol as part of their routine surgical preparation [27]. The scans were reconstructed (Robin's 3D Software) and femoral and tibial frames of reference were established. The radii of the medial and lateral flexion facets (LFF) were measured from spheres best fit to markers placed evenly across their surfaces, on the posterior aspect of the femur. To measure the radius of the medial extension facet (MEF), the femur was initially orientated so that its inferior aspect faced anteriorly and the flexion facets faced superiorly. The anterior and posterior borders of the MEF were then distinguished with markers located using the sagittal CT views. The posterior border defined the transition of the extension facet to the flexion facet, and the anterior border defined the transition from the extension facet to the trochlea. The bony surface between these two borders was subsequently also covered with markers and a sphere best fit to their positions. The radius of the sphere was determined as the MEF radius. The radii of the medial and lateral tibial plateaus (MTP and LTP, respectively) were measured 20 mm below the most proximal aspect of the tibial spines. All measures were normalised to the medial flexion facet as this structure is relatively well preserved in OA.

2.3. Statistical analysis

Participants were separated into three age groups as follows; 18–30, 31–59 and 60+ years. Data from the left and right sides were averaged for healthy participants, and data for the affected and unaffected sides of OA participants were presented separately. All statistical analysis was carried out in SPSS (SPPS v21, IBM Corp, USA). Initially, multiple analysis of variance (MANOVA) was carried out to assess the overall effects of age and OA group. Where the MANOVA attained significance multiple comparisons were carried out using one-way analysis of variance (ANOVA), two sample *t*-tests (OA versus healthy) and paired *t*-tests (OA unaffected versus affected sides). Linear regression was used to assess the relationship between structural measures and knee joint kinetics in the subset of OA participants that underwent CT imaging.

3. Results

Healthy and OA subject details and spatio-temporal gait parameters for each age category are provided in Table 1. MANOVA revealed significant differences between OA and healthy participants for weight ($p < 0.01$), walking speed ($p < 0.001$) and stride length ($p < 0.05$). There was no effect of age group on these parameters and no interaction ($p > 0.05$). Post hoc analysis revealed that OA participants were significantly heavier, walked slower and with shorter stride lengths in the 60+ age category (Table 1).

All kinematic and kinetic data have been presented in Tables 2 and 3. MANOVA for gait parameters revealed significant effects of both OA ($p < 0.001$) and age ($p < 0.001$) group, and significant interactions ($p < 0.005$). Post hoc analysis revealed that coronal plane hip ($p < 0.001$) and knee ($p < 0.05$) angles and knee moment ($p = 0.001$), and sagittal plane ankle moment ($p < 0.001$) were affected by OA presence. Parameters effected by age group were coronal plane hip ($p < 0.05$) and knee ($p < 0.01$) angles and knee moment ($p = 0.002$), and sagittal plane knee angle ($p < 0.05$). Further statistical tests were carried out on these parameters only.

Table 1
Mean (SD) age, height and weight of healthy and osteoarthritis (OA) participants, separated into age categories (*$p < 0.05$ compared with healthy of same age category).

	Healthy			OA	
Age Group	18–30 years (n = 25)	31–59 years (n = 36)	60+ years (n = 23)	31–59 years (n = 13)	60+ years (n = 12)
Age (years)	25.8 (2.8)	43.9 (7.7)	66.8 (5.6)	49.5 (8.6)	67.6 (3.6)
Gender	12M;13F	18M;18F	8M;15F	6M;7F	7M;5F
Height (m)	1.70 (0.13)	1.73 (0.10)	1.67 (0.06)	1.70 (0.13)	1.68 (0.13)
Weight (kg)	64.4 (12.1)	70.4 (13.2)	68.1 (11.0)	78.2 (19.6)	78.9 (15.1)*
Speed (m/s)	1.19 (0.13)	1.18 (0.14)	1.13 (0.28)	1.09 (0.12)	1.02 (0.17)*
Stride length (m)	1.32 (0.14)	1.32 (0.10)	1.24 (0.03)	1.26 (0.12)	1.22 (0.15)*
Stance width (mm)	115.8 (28.9)	123.3 (26.9)	117.8 (25.1)	133.8 (30.7)	110.9 (42.7)