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Predicting knee osteoarthritis risk in injured populations

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ABSTRACT

Background: Individuals who suffered a lower limb injury have an increased risk of developing knee osteoarthritis. Early diagnosis of osteoarthritis and the ability to track its progression is challenging. This study aimed to explore links between self-reported knee osteoarthritis outcome scores and biomechanical gait parameters, whether self-reported outcome scores could predict gait abnormalities characteristic of knee osteoarthritis in injured populations and, whether scores and biomechanical outcomes were related to osteoarthritis severity via Spearman's correlation coefficient.

Methods: A cross-sectional study was conducted with asymptomatic participants, participants with lower-limb injury and those with medial knee osteoarthritis. Spearman rank determined relationships between knee injury and outcome scores and hip and knee kinetic/kinematic gait parameters. K-Nearest Neighbour algorithm was used to determine which of the evaluated parameters created the strongest classifier model.

Findings: Differences in outcome scores were evident between groups, with knee quality of life correlated to first and second peak external knee adduction moment (0.47, 0.55). Combining hip and knee kinetics with quality of life outcome produced the strongest classifier (1.00) with the least prediction error (0.02), enabling classification of injured subjects gait as characteristic of either asymptomatic or knee osteoarthritis subjects. When correlating outcome scores and biomechanical outcomes with osteoarthritis severity only maximum external hip and knee abduction moment (0.62, 0.62) in addition to first peak hip adduction moment (0.47) displayed significant correlations.

Interpretation: The use of predictive models could enable clinicians to identify individuals at risk of knee osteoarthritis and be a cost-effective method for osteoarthritis screening.

1. Introduction

Knee osteoarthritis (OA), a chronic degenerative joint disease, is a major cause of pain and disability creating a huge and continuously growing burden on individuals and society (Creaby et al., 2012; Kaufman et al., 2001; Mundermann et al., 2005). Knee OA is characterised by slow progression, with clinical diagnosis only possible at a late stage of the disease (Glyn-Jones et al., 2015). Therefore modifying interventions to slow and palliate disease advancement are limited if any, leaving joint replacement the mainstay of care. Early disease detection, however, could allow for a larger window of opportunity during which mitigating action could be taken before the onset of irreversible changes and aggravating disabilities (Chu et al., 2012).

Radiographic techniques are conventionally employed in the diagnosis of OA despite a poor correlation between radiographic findings and symptoms, and their ability to identify only the advanced stages of knee OA (Chu et al., 2012; Glyn-Jones et al., 2015). If the burden of OA is to be reduced, novel approaches for early clinical detection need to be identified. Magnetic Resonance Imaging (MRI) is sensitive in detecting structural changes in the knee joint, far exceeding that of conventional radiographs (Guermazi et al., 2009; Wirth et al., 2011) suggesting their use for early detection. However, with MRI techniques costing in the region of £400–£500 per scan it makes them unsuitable for large scale clinical trials and clinical translation. Recent research has explored using OA biomarkers, whilst these have shown promise their routine use remains a distant prospect (Glyn-Jones et al., 2015).

Less attention has been paid to the use of biomechanical markers of early OA. These can be assessed during gait analysis sessions and can typically be conducted at lower cost to MRI's (Patrick, 2003) and unlike MRI's, both legs can be analysed at once. Previous studies have shown characteristic patterns of knee OA, particularly at a late stage (Kaufman et al., 2001). However differences can also be appreciated in early OA with findings of asymmetrical weight distribution during sit-to-stand, as well as postural deficits and altered hip adduction moments during one-

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leg standing (Duffell et al., 2013; Duffell et al., 2014b). Astephen et al. (2008) highlighted how biomechanical mechanisms at the hip, knee and ankle were important when discriminating between individuals with moderate to severe knee OA. It is difficult however, from the cross-sectional nature of the study to infer if changes were due to disease progression or compensatory behaviours.

Individuals with a history of lower limb and knee injury have been found to have a four-fold increased risk of developing knee OA, with diagnosis occurring approximately 10 years earlier (Driban et al., 2014; Muthuri et al., 2011). Assessment of movement biomechanics in this group may prove useful in identifying early mechanical changes associated with knee OA development, allowing us to determine if early abnormalities that are characteristic of knee OA can be detected in injured "high risk" populations, thereby improving early diagnosis of OA allowing for early treatment strategies and ultimately OA prevention.

This study aims to identify the biomechanical parameters which are associated with functional and quality of life outcomes (knee injury and osteoarthritis outcome score (KOOS)) in OA and injured groups. In addition we will investigate whether KOOS outcomes and biomechanical parameters that are characteristic of knee OA can be used to predict early OA onset in injured populations. Finally we will explore whether a relationship exists between KOOS and biomechanical parameters in relation to radiographic knee OA severity.

2. Methods

2.1. Participants

This study was approved by the South West London Research Ethics Committee. All participants gave written informed consent prior to taking part.

The study included: 84 asymptomatic participants (control group), 41 with clinical and radiographic evidence of medial compartment knee OA (OA group; defined as a minimum 15–25% joint space narrowing in the medial compartment of their diseased knee (Duffell et al., 2014b)), and 51 participants with a history of musculoskeletal lower limb injury/surgery (injury group; fracture of the femur, knee or lower part of the leg, previous knee ligament, tendon, or meniscus injury). Due to the exploratory nature of the study, retrospective power calculations conducted post-testing indicated that a sample size of 12 for each of the control, injury and OA groups would give the study a power of 0.9. Both OA and injury participants were separated into unilateral (U-OA (31), U-I (41)) and bilateral (B-OA (10), B-I (10)). OA participants were grouped as unilateral or bilateral based on the number of knees presenting clinical symptoms and joint space narrowing as determined from radiographic images (confirmation by a consultant radiologist). Similarly, injured participants were grouped based on previous GP diagnoses of lower-limb injury. Control and injured participants were recruited from staff and students from Imperial NHS Trust and Imperial College London and posters circulated in hospitals/gyms/local health centres. OA participants were recruited from Imperial NHS Trust and local district regional hospitals.

Participants were excluded if they had neurological, rheumatoid or other systemic inflammatory arthritis, a body mass index (BMI) of > 35 kg/m^2 or had undergone previous surgical treatment for knee OA. Participants were also excluded from the OA groups if they demonstrated other musculoskeletal conditions, were currently taking pain medication or were receiving treatments such as corticosteroid or hyaluronic injections. Knee joints for OA participants were scored for Kellgren and Lawrence (K-L) grade (0–4) from their most recent clinical radiographs (Kellgren and Lawrence, 1957).

2.2. Experimental protocol

A 10 camera Vicon motion capture system (T160, Vicon Motion System Ltd., Oxford, UK) and two portable force plates (Kistler Type 9286B, Kistler Instrumente AG, Winterthur, Switzerland) were used to collect joint kinematics and kinetics as participants walked along a 6 m walkway. Using the protocol described by Duffell et al. (2014a), twenty-three 14 mm diameter retro-reflective markers were positioned on participants' thorax, pelvis and lower limbs with four clusters of three markers positioned on participants' left and right thigh and calf segments; from these joint centres and anatomical frames were defined. Motion capture and force plate data were synchronized and captured at 100 Hz and 1000 Hz respectively. Participants walked 5 times barefoot at self-selected speed.

2.3. Self-reported outcomes

Participants completed a KOOS questionnaire (Roos et al., 1998) to assesses knee health in relation to 5 outcomes, with higher scores indicating less severe symptoms.

2.4. Data analysis

Motion capture and force plate data were processed using the methods described in Duffell et al., 2014a. Kinematic and kinetic

Table 1
Kinetic and kinematic discrete variables measured during gait.

Variable	Definition
Ground reaction force	
Maximum vertical force	Maximum vertical ground reaction force during the 1st 50% of the stance phase
Maximum vertical loading rate	Maximum slope of the vertical ground reaction force during the 1st 10% of the stance phase
Hip	
First peak rotation angle	Maximum vertical hip rotation angle during the stance phase of the gait cycle
Flexion angle RoM	Maximum hip angle calculated from maximum flexion to maximum extension during gait cycle
Abduction/adduction angle RoM	Maximum hip angle calculated from maximum hip abduction to maximum hip adduction during the gait cycle
Maximum external abduction moment	Maximum abduction moment of the hip during the 1st 20% of the stance phase
First peak external adduction moment	Maximum adduction moment of the hip during the 1st 50% of the stance phase
Second peak external adduction moment	Maximum adduction moment of the hip during the 2nd 50% of the stance phase
Knee	
First peak flexion angle	Maximum flexion angle during the stance phase of the gait cycle
Second peak flexion angle	Maximum flexion angle during the swing phase of the gait cycle
Flexion angle RoM	Maximum knee angle calculated from maximum flexion to maximum extension during the gait cycle
Maximum abduction moment	Maximum abduction moment of the knee during the 1st 20% of the stance phase
First peak external adduction moment	Maximum adduction moment of the knee during the 1st 50% of the stance phase
Second peak external adduction moment	Maximum adduction moment of the knee during the 2nd 50% of the stance phase

RoM = Range of Motion.