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Kinematics of knees with osteoarthritis show reduced lateral femoral roll-back and maintain an adducted position. A systematic review of research using medical imaging

Jennie M. Scarvell [a,b,*], Catherine R. Galvin [a,b], Diana M. Perriman [b,c,a], Joseph T. Lynch [b,c], Robert W.M. van Deursen [d,e]

[a] University of Canberra, Australia
[b] Trauma and Orthopaedic Research Unit, Canberra Hospital, Australia
[c] Australian National University, Australia
[d] Cardiff University, United Kingdom
[e] Arthritis Research UK Biomechanics and Bioengineering Centre, Cardiff, United Kingdom

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ABSTRACT

Background: While several studies describe kinematics of healthy and osteoarthritic knees using the accurate imaging and computer modelling now possible, no systematic review exists to synthesise these data.

Method: A systematic review extracted quantitative observational, quasi-experimental and experimental studies from PubMed, Scopus, Medline and Web of Science that examined motion of the bony or articular surfaces of the tibiofemoral joint during any functional activity. Studies using surface markers, animals, and in vitro studies were excluded.

Results: 352 studies were screened to include 23 studies. Dynamic kinematics were recorded for gait, step-up, kneeling, squat and lunge and quasi-static squat, knee flexion in side-lying or supine leg-press. Kinematics were described using a diverse range of measures including six degrees of freedom kinematics, contact patterns or the projection of the femoral condylar axis above the tibia. Meta-analysis of data was not possible since no three papers recorded the same activity with the same measures. Visual evaluation of data revealed that knees with osteoarthritis maintained a more adducted position and showed less posterior translation of the lateral femoral condylar axis than healthy knees. Variability in activities and in recording measures produced greater variation in kinematics, than did knee osteoarthritis.

Conclusion: Differences in kinematics between osteoarthritic and healthy knees were observed, however, these differences were more subtle than expected. The synthesis and progress of this research could be facilitated by a consensus on reference systems for axes and kinematic reporting.

1. Introduction

Osteoarthritis of the knee affects 18.2% of people in the UK over 45 years, which was 4.11 million people in 2017 (Arthritis Research UK, 2017). In Australia, total knee replacement is the most common surgical procedure requiring hospital admission (Australian Institute of Health and Welfare, 2015). With osteoarthritis imposing such a heavy burden of disease, there is intense interest in evidence-based solutions.

Much of the current understanding of knee kinematics in osteoarthritis is due to research using motion and kinetic analysis. Disease progression has influenced temporospatial characteristics of gait (Kaufman et al., 2001; Zeni and Higginson, 2009); and increased adductor moment (Hurwitz et al., 1999; Andriacchi and Mundermann, 2006), varus thrust (Sharma et al., 2001) and muscle co-contraction have been validated as predictors of progression (Lewek et al., 2004; Hodges et al., 2016). These insights have informed current non-surgical management approaches (Simic et al., 2011; Fregly, 2012; Farrokhi et al., 2013). However, a recent systematic review did not find evidence of increased knee

* Corresponding author at: 12 D 35, Faculty of Health, University of Canberra, Bruce, ACT 2601, Australia.
E-mail addresses: jennie.scarvell@canberra.edu.au (J.M. Scarvell), Catherine.galvin@canberra.edu.au (C.R. Galvin), diana.perriman@act.gov.au (D.M. Perriman), joe.lynch@act.gov.au (J.T. Lynch), vandeursenr@cardiff.ac.uk (R.W.M. van Deursen).

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adduction moment nor loss of internal rotation, demonstrating that aspects of kinematics in osteoarthritis still need explanation (Mills et al., 2013).

Recently, advances in medical imaging and computerised reconstruction have facilitated visualisation and modelling of the articular surface thereby ushering in the next generation of kinematic analysis. In its earliest form, roentgen photogrammetric analysis (RSA) using biplanar X-ray was highly accurate but invasive, consequently its application was constrained to surgical participants in small numbers (Karrholm et al., 2000; Saari et al., 2005; Weidow, 2006). More recently CT and MRI have been used to provide a 3-dimensional model, which when registered to fluoroscopy, provides 4-dimensional analysis (Li et al., 2005; Hamai et al., 2009; Pickering et al., 2009; Koga, 2015). Fluoroscopy units are now capable of capture rates of up to 250 frames per second (You et al., 2001) and image registration algorithms can provide precision of less than one millimetre and one degree (DeFrate et al., 2006; Akter et al., 2015; Zeighami et al., 2017). Computer algorithms for 4D CT are also being developed (Alta et al., 2012). In this environment, previously unavailable accuracy in joint-level kinematics is emerging.

It is therefore timely to review whether current computational imaging can define the kinematic characteristics of osteoarthritis at the articular surface level (arthrokinematics). Individual studies have reported reduced flexion range of motion in addition to reduced posterior translation of the femoral condyles across the tibial plateau associated with flexion (Saari et al., 2005; Scarvell et al., 2007). But there is a lack of agreement (Saari et al., 2005; Hamai et al., 2009) and the information has not been gathered into a cohesive review to identify the specific characteristics of joint movement in knee osteoarthritis.

This systematic review therefore asks what are the characteristics of arthrokinematics of the knee with osteoarthritis that deviate from healthy knee kinematics.

2. Method

This study was designed according to PRISMA guidelines and registered with Prospero (CDR42017072481) prior to commencement (Box 1).

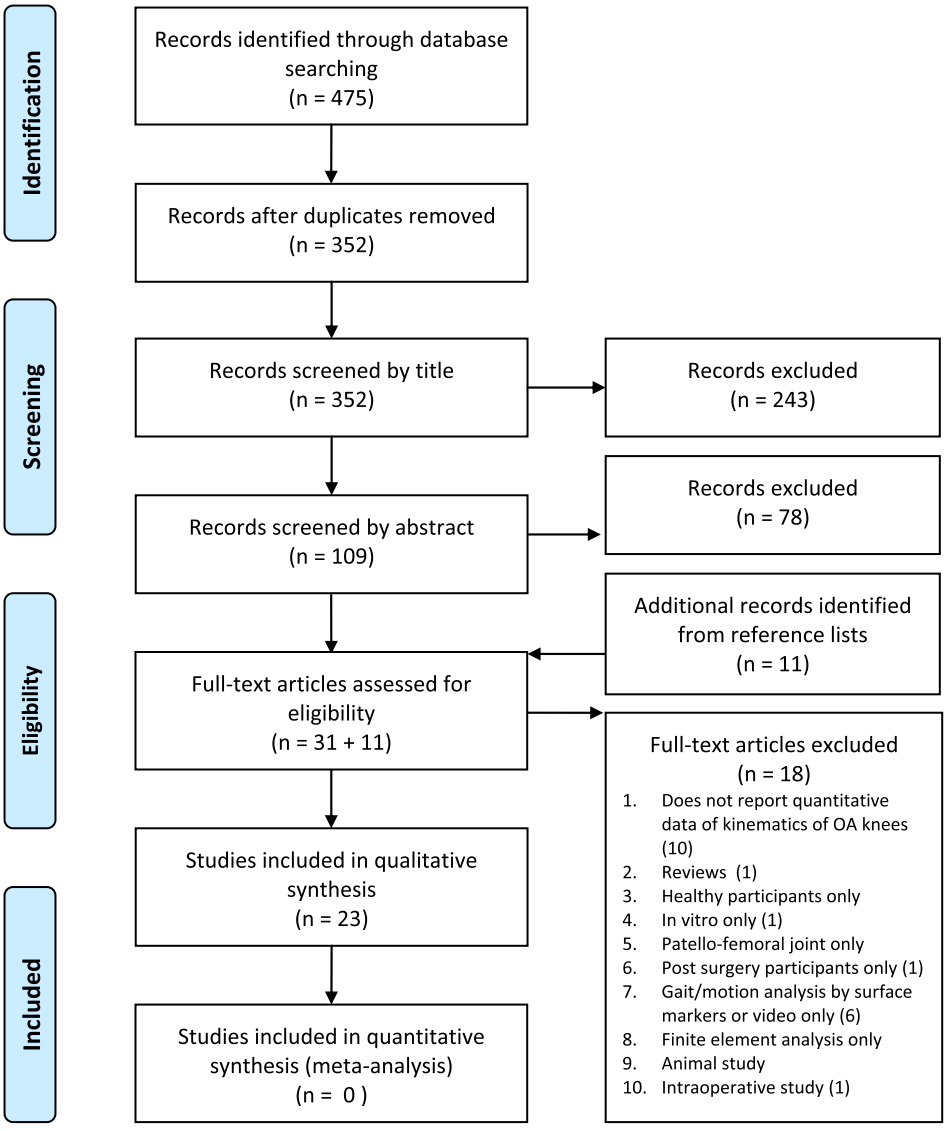

Fig. 1. Flow chart of papers included in the systematic review.

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