



Gait characteristics and lower limb muscle strength in women with early and established knee osteoarthritis

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ABSTRACT

Background: Based on novel classification criteria using magnetic resonance imaging, a subpopulation of “early knee osteoarthritis patients” was clearly defined recently. This study assessed whether these early osteoarthritis patients already exhibit gait adaptations (knee joint loading in particular) and changes in muscle strength compared to control subjects and established knee osteoarthritis patients.

Methods: Fourteen female patients with early knee joint degeneration, defined by magnetic resonance imaging (early osteoarthritis), 12 female patients with established osteoarthritis and 14 female control subjects participated. Specific gait parameters and lower limb muscle strength were analyzed and compared between groups. Within the osteoarthritis groups, association between muscle strength and dynamic knee joint loading was also evaluated.

Findings: Early osteoarthritis patients presented no altered gait pattern, no significant increase in knee joint loading and no significant decrease in hamstring muscle strength compared to controls, while established osteoarthritis patients did. In contrast, early osteoarthritis patients experienced significant quadriceps weakness, comparable to established osteoarthritis patients. Within the osteoarthritis groups, muscle strength was not correlated with knee joint loading during gait.

Interpretation: The results suggest that gait changes reflect mechanical overload and are most likely the consequence of structural degeneration in knee osteoarthritis. Quadriceps weakness might however contribute to the onset and progression of the disease. This study supports the relevance of classification of early osteoarthritis patients and assists in identifying their functional characteristics. This helps to understand the trajectory of disease onset and progression and further develop more targeted strategies for prevention and treatment of knee osteoarthritis.

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1. Introduction

Knee osteoarthritis (OA) is the most common chronic joint disease and a major cause of pain and functional impairment in the aging population (Guccione et al., 1994). It is more common among women than men (Blagojevic et al., 2010) and the prevalence is expected to increase due to aging of the population and rising prevalence of obesity (Murphy et al., 2008). Given this anticipated increase in knee OA prevalence and related increase in economic costs (Rabenda et al., 2006), the need to identify risk factors for development and progression of knee OA is of key importance to optimize patient management.

Several functional parameters have been studied in knee OA patients. However, these studies mostly include patients in a range of OA disease severity stages, as evaluated by the Kellgren and Lawrence (K&L) scale

on radiography (Kellgren and Lawrence, 1957). Recently, there is an increasing interest in specifically identifying a subpopulation of “early knee OA patients” (Ding et al., 2010; Luyten et al., 2012). This cohort typically combines recurrent knee pain with structural changes not detected on conventional X-rays. Yet, the altered structural characteristics that are considered early degenerative joint changes are observed by arthroscopy or magnetic resonance imaging (MRI). Therefore it may be advantageous to explore whether these early OA patients with early or mild joint degeneration also present functional impairments when compared to “healthy knees”. This might be helpful in understanding the trajectory of disease onset and progression (Luyten et al., 2012).

It is well known knee OA patients alter their gait compared to controls (Astefhen et al., 2008a; Baliunas et al., 2002; Sharma et al., 1998). Given the role of aberrant knee joint loading in pathogenesis, the external knee adduction moment (KAM) which is a surrogate measure that is used to infer the medial compartment loading of the knee joint during walking (Birmingham et al., 2007) has received particular attention (Bennell et al., 2011; Miyazaki et al., 2002; Sharma et al., 1998). The peak KAM

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and KAM impulse, which incorporates not only magnitude but also duration of the KAM, are significantly increased in knee OA patients, presenting indirect evidence of an increase in total knee joint loading during walking (Baliunas et al., 2002; Gok et al., 2002; Thorp et al., 2006). The KAM is reported to be higher with greater OA severity, with magnitudes being lower with moderate severity (Sharma et al., 1998; Thorp et al., 2006; Wada et al., 2001). However, there is no evidence that less severe knee OA patients have an increased KAM compared to healthy controls (Foroughi et al., 2009). Consequently, whether mechanical knee loading is already altered for OA patients with early or mild knee severity remains unknown.

Muscle strength significantly contributes to knee joint loading during walking (Pandy and Andriacchi, 2010) with recent attention being focused on lower limb muscle strength among knee OA patients. While quadriceps muscle weakness is well documented among knee OA patients (Lewek et al., 2004b; Palmieri-Smith et al., 2010; Tan et al., 1995), hamstring muscle strength is less studied and the results are contradictory (Slemenda et al., 1998; Tan et al., 1995). New evidence suggests hip muscles to be weaker in knee OA patients than in controls (Costa et al., 2010; Hinman et al., 2010). To date, it remains unknown whether lower limb muscle weakness is already present in early knee OA patients.

Therefore the objective of this study was to evaluate whether early knee OA patients, evidenced by early joint degeneration on MR images as described by Luyten et al., 2012, already exhibit gait adaptations (knee joint loading in particular) and lower limb muscle strength deficits compared to control subjects. This study may strengthen the newly proposed classification criteria of early knee OA and may provide opportunity towards a more targeted approach for risk identification and management of knee OA patients.

2. Methods

2.1. Participants

Forty women participated in this study. Subject characteristics are listed in Table 1. All procedures were approved by the local ethical committee of Biomedical Science, KU Leuven, Belgium. A written informed consent was obtained from each subject. The study was conducted in accordance with the declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects.

All participants were referred for a physical exam and standard anterior-posterior weight-bearing radiographs in fixed flexed position were taken bilaterally (Siemens, Siregraph CF, Agfa CR HD5.0 detector 24*30). Each radiograph was graded by a single experienced observer (FPL) to confirm and classify presence of structural knee OA based on the K&L grading scale with recent adjustment (Felson et al., 2011). The intra- and inter-rater reliability of the K&L grading scale is high ($r > 0.85$) (Kessler et al., 1998). The (most) affected side (clinical and structural) for all OA patients and the side with K&L grade 0 (bicompartimental) for controls was selected for further analysis. For all participants, MRI of this selected knee was performed on a 3.0 T scanner (Philips Achieva TX, Philips Medical Systems, Best, The Netherlands) using an eight-channel phased array knee coil in a non-weight bearing supine position. Semiquantitative scoring of specific structural features in the tibiofemoral joint was performed separately by two readers (NN, GVDS) using the standardized Boston-Leeds Osteoarthritis Knee Score (BLOKS) scoring system (Hunter et al., 2008). For 91% of all scored items full agreement between both readers was achieved. Disagreements were resolved by consensus.

Table 1

Characteristics of control subjects, patients with early OA and patients with established OA*.

Characteristics	Control <i>n</i> = 14	Early OA <i>n</i> = 14	Established OA <i>n</i> = 12	<i>P</i>	<i>P</i>	<i>P</i>	<i>P</i>
					established vs. control	early vs. control	established vs. early
Age, years ^a	65.8 (9.9)	65.4 (8.9)	68.3 (6.8)	0.662			
Weight, kg ^a	63.4 (9.0)	72.0 (13.4)	73.1 (11.5)	0.069			
Height, m ^a	1.60 (0.06)	1.63 (0.06)	1.60 (0.05)	0.261			
BMI, kg/m ² ^a	24.8 (3.2)	27.1 (5.2)	28.6 (4.1)	0.082			
KOOS pain score ^b	100 (0)	72.2 (25)	68 (26.4)	<0.001 [†]	<0.001 [†]	<0.001 [†]	1.412
KOOS symptoms score ^b	98.2 (3.6)	76.8 (14.3)	62.5 (16.1)	<0.001 [†]	<0.001 [†]	<0.001 [†]	0.079
KOOS ADL score ^b	100 (0)	83.8 (27.9)	66.2 (22.1)	<0.001 [†]	<0.001 [†]	<0.001 [†]	1.461
SCT, s ^a	5.59 (1.01)	6.29 (1.60)	6.69 (1.80)	0.183			
TUG, s ^a	5.09 (0.88)	5.75 (0.99)	5.87 (1.73)	0.219			
Static alignment ^c				0.143			
Neutral	43% (<i>n</i> = 6)	71% (<i>n</i> = 10)	42% (<i>n</i> = 5)				
Valgus	36% (<i>n</i> = 5)	7% (<i>n</i> = 1)	8% (<i>n</i> = 1)				
Varus	21% (<i>n</i> = 3)	21% (<i>n</i> = 3)	50% (<i>n</i> = 6)				
Medial compartment K&L score	Grade 0: <i>n</i> = 14	Grade 0: <i>n</i> = 3 Grade 1: <i>n</i> = 9 Grade 2 ⁺ : <i>n</i> = 2	Grade 2 ⁺ : <i>n</i> = 7 Grade 3: <i>n</i> = 3 Grade 4: <i>n</i> = 2				
Self selected walking speed, m/s ^a	1.16 (0.20)	1.15 (0.11)	1.08 (0.14)	0.347			
Stride length, m ^a	0.94 (0.09)	0.83 (0.27)	0.90 (0.15)	0.263			
Step length, m ^a	0.39 (0.08)	0.36 (0.13)	0.37 (0.11)	0.636			
Step width, m ^a	0.20 (0.02)	0.23 (0.10)	0.21 (0.02)	0.318			
Stance duration (% gait cycle) ^a	63.3 (3.8)	66.0 (6.6)	66.1 (5.2)	0.309			
Swing duration (% gait cycle) ^a	36.7 (3.8)	34.0 (6.6)	33.9 (5.2)	0.309			
Initial DS duration (% gait cycle) ^a	8.6 (1.4)	9.6 (2.0)	11.0 (1.7)	0.004 [†]	0.003 [†]	0.302	0.099
Terminal DS duration (% gait cycle) ^a	11.0 (2.2)	11.1 (2.2)	13.0 (2.3)	0.051			
Midstance duration (% gait cycle) ^a	43.7 (4.1)	45.3 (5.5)	42.1 (3.6)	0.214			

OA = osteoarthritis; BMI = Body mass index; KOOS = Knee injury and osteoarthritis outcome score (range 0–100); ADL = Activities of daily living; SCT = Stair climbing test; TUG = Timed up and go test; K&L = Kellgren & Lawrence (range 0–4); DS = double stance.

* Data are presented as mean (SD)^a or median (IQR)^b. The *P*-value corresponds to an ANOVA (with post hoc tests) ^a, Kruskal–Wallis test (with post hoc tests)^b or Fisher's exact test ^c comparing the three groups.

[†] Significant difference between groups ($P < 0.05$).

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