Can gait patterns in knee osteoarthritis patients be explained or predicted by joint structure?

UMC Utrecht

M.P. Jansen[1], D. Hodgins[2], S.C. Mastbergen[1], M. Kloppenburg[3], F.J. Blanco[4], I.K. Haugen[5], F. Berenbaum[6], F.P.J.G. Lafeber[1], F.W. Roemer[7], W. Wirth[8]

[1]University Medical Center Utrecht, Utrecht, The Netherlands; [2]Dynamic Metrics Limited, Codicote, UK; [3]Leiden University Medical Center, Leiden, The Netherlands; [4]INIBIC-Hospital Universitario A Coruña, A Coruña, Spain; [5]Diakonhjemmet Hospital, Oslo, Norway; [6]Sorbonne University, INSERM, AP-HP Saint-Antoine hospital, Paris, France; [7]Universitätsklinikum Erlangen, Erlangen, Germany & Boston University School of Medicine, Boston, US; [8]Paracelcus Medical University, Salzburg, Austria & Chondrometrics GmbH, Freilassing, Germany

Purpose

In patients with knee osteoarthritis, gait can be affected. This might be the result of structural joint alterations, and could be modified by training. The purpose of this study was to analyze whether 1) gait patterns can be explained by joint structure and 2) longitudinal gait alterations can be predicted by joint structure in people with knee osteoarthritis (OA).

Methods

- In the IMI-APPROACH cohort, 297 participants with knee OA were included at 5 sites in Europe. At multiple time points, including at baseline and two years later, full **gait kinematic data** was collected from all participants using the GaitSmart® system (Dynamic Metrics Limited, Codicote, UK). Baseline **radiographs and MRI scans** of their index knee were performed for evaluation of joint structure.
- The GaitSmart measures most relevant and included for the current study were range of motion (**ROM**) of the **hip, thigh, knee** in swing and stance phase, and **calves** in the sagittal plane, and **medial-lateral movement** of the **thigh** and **calf**, all for the index leg. **Stride duration** and **speed** were included as well.
- From the radiographs, the minimum joint space width (**JSW**), **femorotibial angle**, mean whole-joint **subchondral bone density** (SBD), and total whole-joint **osteophyte area** were determined.
- From the MRI scans, mean whole-joint femorotibial **cartilage thickness** (FTC) was determined and **MOAKS** scoring for **synovitis**, **effusion**, **meniscus signal** and meniscal **extrusion** were performed. For the meniscal parameters, the maximum score across all regions was used.
- All GaitSmart parameters were compared between baseline and two years with **paired t-tests** to quantify **gait alterations over two years**. For the comparisons with joint structure, principal component analyses (**PCA**) was performed on the **gait parameters** first, to reduce data and discover underlying **domains**.
- Univariate backwards linear **regression models** with each of the GaitSmart domains as dependent variable were used to analyze **how joint structure influences gait or predicts gait change over two years**. Three models were run: one with **participant demographics** (age, sex, BMI) only, one with **structural imaging parameters** only, and one **combining the first two** models. Further, to analyze whether any joint structure parameter might be associated with the gait domains independent from other structure characteristics, Spearman correlations were performed between baseline joint structure parameters and gait domains.

approach

DYNAMIC METRICS

BOSTON UNIVERSITY

Universitätsklinikum Erlangen

chondrometrics

Results

- 284 Participants (age 66.5±7.1, BMI 28.0±5.4, 65 (23%) male, 154 (54%) radiographic OA) had baseline GaitSmart data (of which 211 also had two-year data).
- PCA identified three gait domains: **upper leg** (speed, duration, thigh ROM and hip ROM), **lower leg** (knee ROM in stance and swing, calf ROM), and **medial-lateral movement** (thigh and calf medial-lateral movement). Over two years the **lower leg** parameters showed a **slight deterioration**, though only knee ROM in swing phase changed significantly (-1.5±6.9 degree, p=0.002). The upper leg parameters showed minor non-significant improvement over two years; the medial-lateral parameters showed opposing non-significant changes.
- Results of all models are summarized in Table 1. Cross-sectionally, male sex and higher BMI were significantly associated with worse upper leg function (i.e. smaller ROM, lower speed) when looking only at demographics (R^2=0.058), while for the joint structure only model, **higher SBD** and absence of synovitis showed significant associations with worse upper leg function (R^2=0.026). Combining demographics and joint structure, **male sex, higher BMI and synovitis absence** were associated with **worst upper leg function** (R^2=0.080). For baseline correlations with structural parameters separately, the upper leg gait domain was significantly negatively correlated with SBD (ρ=-0.13; p=0.026). **Change in upper leg gait** was predicted by sex only, with **male sex** resulting in less function improvement (R^2=0.024).
- For **lower leg gait**, **female sex, higher BMI and bigger osteophytes** lead to worst function (i.e. smaller ROM) cross-sectionally (R^2=0.241), while **lower FTC, presence of effusion and absence of synovitis** would additionally lead to **worse function** as well when excluding demographics (R^2=0.136). For joint structure parameters separately, lower leg gait was significantly positively correlated with minimum JSW (ρ=0.15; p=0.013) and FTC (ρ=0.18; p=0.002) and negatively with SBD (ρ=-0.12; p=0.045), osteophytes (ρ=-0.32; p<0.001), meniscal extrusion (ρ=-0.23; p<0.001), and effusion (ρ=-0.21; p=0.001). **Worsening lower leg gait** could be predicted by **higher age and BMI, presence of synovitis and smaller osteophytes** (R^2=0.094).
- Neither demographics nor joint structure was significantly associated with or predictive for changes in medial-lateral gait.

GaitSmart domain	Model 1: demographics		Model 2: joint structure		Model 3: model 1 + model 2	
	Variables	R^2	Variables	R^2	Variables	R^2
Baseline associations						
Upper leg	• Sex (β=-0.11; p=0.062) • BMI (β=-0.21; p<0.001)	0.058	• SBD (β=-0.14; p=0.027) • Synovitis (β=0.11; p=0.090)	0.026	• Sex (β=-0.14; p=0.018) • BMI (β=-0.23; p<0.001) • Synovitis (β=0.12; p=0.051)	0.080
Lower leg	• Sex (β=0.27; p<0.001) • BMI (β=-0.28; p<0.001)	0.142	• FTC (β=0.11; p=0.059) • Osteophytes (β=-0.26; p<0.001) • Synovitis (β=0.15; p=0.023) • Effusion (β=-0.16; p=0.022)	0.136	• Sex (β=0.30 p<0.001) • BMI (β=-0.23; p<0.001) • Osteophytes (β=-0.33; p<0.001)	0.241
Medial-lateral	None	-	None	-	None	-
Two-year change prediction						
Upper leg	• Sex (β=-0.15; p=0.026)	0.024	None	-	• Sex (β=-0.15; p=0.026)	0.024
Lower leg	• Age (β=-0.17; p=0.016) • BMI (β=-0.18; p=0.010)	0.048	• Osteophytes (β=0.175; p=0.017) • Synovitis (β=-0.21; p=0.004)	0.053	• Age (β=-0.14; p=0.046) • BMI (β=-0.17; p=0.014) • Osteophytes (β=0.20; p=0.006) • Synovitis (β=-0.18; p=0.013)	0.094
Medial-lateral	None	-	None	-	None	-

Table 1: Baseline associations and two-year prediction of changes in the different gait domains, for participant demographics (model 1), joint structure (model 2), and a combination (model 3).
FTC: femorotibial cartilage thickness; SBD: subchondral bone density. Sex was coded 1 for female and 2 for male.

Conclusions

Joint structure could partially explain gait and even predict gait changes in people with knee OA especially for the lower leg, providing a significant association between OA symptoms and joint structure, although only for a limited part (low R^2 values) and not for medial-lateral movement. Surprisingly, synovitis and osteophyte size showed contrasting associations with lower leg gait that may be explained by half of the patients not having radiographic OA. This should be investigated further. Parameters indicating more severe OA (e.g. lower JSW and FTC, higher age and SBD) were generally associated with more impaired gait.

Acknowledgements

The research leading to these results have received support from the Innovative Medicines Initiative Joint Undertaking under Grant Agreement no 115770, resources of which are composed of financial contribution from the European Union's Seventh Framework Programme (FP7/2007-2013) and EFPIA companies' in kind contribution. See www.imi.europa.eu and www.approachproject.eu.

University Medical Center Utrecht

m.p.jansen-36@umcutrecht.nl

URCI