Perceived personal impact and selected gait features of knee osteoarthritis among active older women with mild-moderate radiographic disease: extent, interrelationships and implications

Background: Factors other than pain that may impact the disease experience of adults with mild to moderate manifestations of knee osteoarthritis are poorly documented.

Objective: To examine the extent of the association between selected gait parameters and the overall perceptual experience of women with mild to moderate knee osteoarthritis

Method: The relationship between the emergent gait correlates of interest among 18 women, selected randomly from a cohort of 71 knee osteoarthritis cases, and their Arthritis Impact Measurement Scale scores were assessed on a single occasion using standard procedures.

Results: 1. There was a strong inverse association between the subject's impact scores and their self-paced walking speed records, as well as their stride length scores (p<0.05). 2. Those who could walk further in a period of six minutes tended to be less impacted by the disease than those who walked shorter distances (p<0.05). 3. The strongest predictor of self-assessed arthritis impact was the stride length measure (r=-.65) 4. Those with asymmetrical gait features had worse impact scores, as well as gait parameter scores.

Conclusion: Careful gait assessments, and efforts to optimize stride length and gait symmetry, may help to reduce the aversive impact of knee osteoarthritis in mild-moderate cases.

Ray Marks*

Department of Health & Behavior Studies, School of Health & Behavioral Sciences, Teachers College, Columbia University, New York, USA

*Author for correspondence:
rm226@columbia.edu

Background

Osteoarthritis (OA), a highly prevalent joint disease causes appreciable disability in the majority of adults over 55 years of age [1]. The knee, a joint frequently affected by osteoarthritis [2,3], produces considerable pain and activity limitations [4], especially in women [5,6]. Studies comparing healthy older women with and without knee osteoarthritis have shown the latter to experience decreased survival rates [7], plus a highly negative individual and collective socio-economic impact [8-10]. Associated with an array of highly destructive processes [11-15], knee osteoarthritis often impairs general health, vitality, and mobility quite significantly and adversely [16-20]. As a result, individuals with this disease have a high risk of incurring a poor life quality [21], and a much reduced functional and work capacity [22].

Since the disease is not curable, and is generally progressive, and does not respond resoundingly to pharmacologic interventions, efforts to carefully examine and tease out what factors exacerbate this downward spiral of events, may help to identify points of intervention that can minimize the disease progression.

Based on a reasonably voluminous literature on the impact of knee osteoarthritis on walking ability, and the fact that walking speed is found to be valid predictor of future osteoarthritis disability among older adults [23,24], we elected to examine whether there is a linkage between selected gait characteristics of subjects with mild joint disease and their subjective perception of the global impact of their health condition on their wellbeing-which is often predictive of their motivation to adhere to self-management strategies.

It was anticipated that if a significant linkage could be demonstrated, future work to offset the excess disability especially notable among older women diagnosed as having mild to moderate knee joint osteoarthritis, might be forthcoming.

The specific research questions of interest were:

How strongly does the knee osteoarthritis impact active older community dwelling individuals with mild to moderate unilateral or bilateral knee osteoarthritis?

Regardless of magnitude of impact, is there a linear association between these perceptions and selected spatio-temporal gait characteristics such as walking speed, and stride length?

Are patients with knee osteoarthritis and asymmetrical gait patterns likely to be impacted more negatively than those who are not?

What can the data reveal that will help advance recommendations for reducing the risk of excess disability specifically among active older women with mild-moderate knee joint osteoarthritis?

Materials & methods

Sample and procedures

Available data from a random sample of a larger non probability convenience sample was examined. The cohort consisted of 18 women diagnosed as having mild to moderate knee osteoarthritis of one or both knee joints, who were free living community dwelling members with radiological evidence of knee osteoarthritis of either the medial or lateral compartment of one or both knees of grade II severity (i.e. joint space narrowing, osteophytes) recorded in weight-bearing [5]. All were able to walk and none used any assistive device. All fulfilled at least 3 of 6 criteria for clinical osteoarthritis [25].

Subjects with other forms of arthritis, neurological impairments, limb injuries or abnormalities, those eligible for surgery or a history of surgery of the affected knee[s], and those with uncontrollable or unstable medical conditions were excluded. Subjects had to be able to follow instructions or basic English and were referred for assessment as part of a larger study to the study by various physicians in the community. Those that met the study criteria, were requested to provide informed consent.

Measures

To obtain the desired data, all eligible subjects completed a demographic questionnaire and several sub-domains of the Arthritis Impact Measurement Scale (AIMS) that considers the patients medication usage, physical abilities, pain levels, and subjective estimate of how their condition impacts their well-being [26]. Perceived arthritis impact was scored using a single self-rated item on the AIMS that correlated with other AIMS sub-dimensions and asked patients how well they were doing considering all the ways their arthritis affected them by checking the most appropriate response on a 0-10 point visual analogue scale, where 0=very well, 2.5=well, 5.0=fair, 7.5=poor and 10=very poor. Distance walked in 6 minutes at self-paced speed on a standardized level indoor walkway, and gait parameters of stride length and gait cycle duration were captured were electronically, and compared to available data on age and gender matched healthy women. Gait measures recorded bilaterally were deemed to be asymmetrical from side to side if they differed in terms of duration or length for a particular phase of the gait cycle such as stance. Asymmetry also referred to intra individual differences between the ratios obtained for stance versus swing phase duration within subjects.

In sum, the key items assessed were age, perceived impact of condition, and a variety of walking parameters. The goal was to highlight relevant associations of clinical import, other than pain that might be helpful for optimizing patient well-being and slowing disease progression or actual as well as perceived disability.

Statistical analyses

All desired data were recorded on separate survey sheets, and then entered systematically into an Excel spread sheet. The desired descriptive statistics were reported as means+SD, or percentages, and inferential tests including cross tabulations, analysis of variance, and selected correlational analyses were conducted using SPSS version 16.00. The significance level for all tests was set at $p < 0.05$.

Results

The demographic and key clinical features of the sample are shown in Table 1. As outlined, subjects had a mean age of 70.11 years (range 59-84), with a mean arthritis impact score of 3.6, and more subjects were overweight than not, a finding typical of most knee osteoarthritis patients. Most were in fair health, and could complete all the mobility tests without assistance of any sort. When examined separately, the

Table 1: Characteristics of the study sample of 18 women with unilateral or bilateral knee osteoarthritis randomly selected from 71 eligible participants showing means, range and percentage distribution of key variables.

Variables	Value
Age (Years)	
Range	59-84
Mean ± SD	70.2 ± 7.7
Disease duration (range 5-50 Years)	
3-5	29% (N=5)
6-10	33% (N=6)
11-15	22% (N=4)
>20	16% (N=3)
Disease type	
Unilateral	(N=9)
Bilateral	(N=9)
Health Status	
Excellent	11% (N=2)
Good	61% (N=11)
Fair	27% (N=5)
Morbidity count	
Range	0-4
Mean ± SD	1 ± 1.1
Cardiovascular disease	
Yes	(N=12)
No	(N=6)
Body mass index (h.w^{-2})(BMI)	
Range	22.0-35.8
Mean ± SD	27.9 ± 2.9
Arthritis Impact Measurement Score (Range 0-10; Doing Very Well-Doing Very Poorly)	
Range	0-7.5
Mean ± SD	3.6 ± 2.6; median=5
Pain Visual Analogue 0-10 Numeric Rating Scale:	
Range	1.0-10.0
Mean ± SD	4.6 ± 3.1
Six Minute Walking Distance (m)	
Range	199-567
Mean ± SD	350 (119.8)
Self-Paced Velocity (m.min^{-1})	
Range	15.0-74.2
Mean ± SD	48.9 ± 15.6

Table 2: Significant bivariate zero order correlations observed between AIMS impact scores and key functional variables and pain (N=17).

Factors

AIMS Impact Score	Gait cyc [s] [m]	Wlk Dist [m.s^{-1}]	SPVel [m]	Stride Length [0-10]	VAS Pain [0-10]	AIMS Pain
r	.05	-.59	-.54	-.62	.50	.53
p value	0.03 0.03	0.03	0.01	0.04	0.03	

Abbreviations: AIMS Impact: Arthritis Impact Score; AIMS Pain: Aims Pain Score; Gait cyc: Gait Cycle Duration (s); SPVel: Self-paced Walking Velocity; VAS: Visual Analogue Pain Scale Scores; Wlk Dist: Six minute walking Distance on indoor level walkway

impact scores were found to be significantly correlated with several gait variables as outlined in Table 2, including self-paced velocity (r=-.54; p=.03), stride length (r=-.62; p=.01), gait cycle duration (r=.50, p=0.03), and six minute walking distance (r=-.59; p=.03). The extent of the perceived arthritis impact was found to be higher among subjects who exhibited asymmetry as defined with respect to differences in side to side stance phase duration estimates, and this association was significant at the p=.04 level (Figure 1).
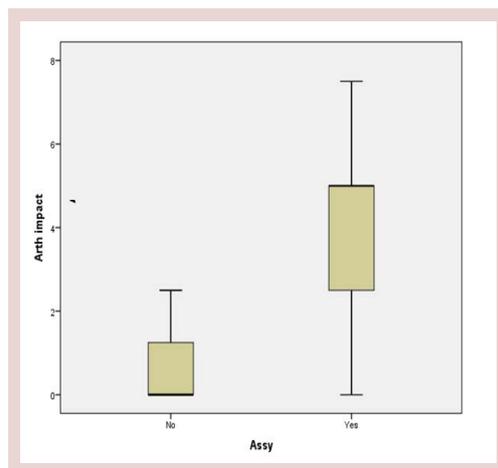
Figure 1: Descriptive relationship between Arthritis Impact Scores (Arth Impact-0-10) and presence or absence of Inter Limb Asymmetry (ASSY) (Y=yes; N=no).
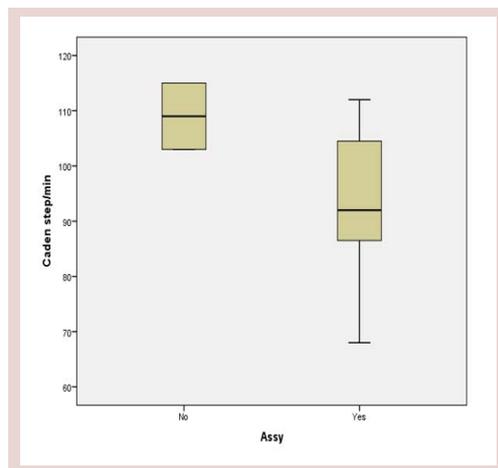

Figure 2: Descriptive relationship between Cadence Scores when Walking at Self-Paced Speed (Steps per Minute] and presence or absence of Inter Limb Asymmetry (ASSY) (Y=yes; N=no).

As well, asymmetry influenced self-paced walking velocity, cadence or number of steps per minute (Figure 2), walking distance in six minutes, and total double support duration adversely, regardless of numbers of affected joints, and was present in all but 3 of the women studied, and overall the correlation between single support estimates for right leg versus left leg for the sample was r=.56, suggesting the relationship is not a symmetrical one. This was evident for 15/18 cases were the single support time differed from side to side, and in an inconsistent way, where 5 cases (or 33%; 2 bilateral cases versus 3 unilateral cases) had longer support times on the left than on the right. Those with equitable support times were mostly bilateral knee osteoarthritis cases (or 2/3 patients).

Discussion

Osteoarthritis, an age-related disease of the articular cartilage lining of a joint, produces a multi-dimensional clinical syndrome, which commonly includes symptoms of pain. Associated with pathological changes that include joint effusion, stiffness, decreased range of joint motion, joint instability and malalignment, among the various causative factors that have been expounded, are repetitive impulsive forces during walking [27], or aberrant joint loading, which may produce subtle alterations in joint structure over various periods of time [28]. The aim of this study was to investigate the association between the perceived impact of the disease and selected gait parameters including the degree of gait symmetry exhibited during level walking at two speeds among women with mild-moderate symptomatic knee osteoarthritis. It was hypothesized that the impact of osteoarthritis stems from multiple problems, but that a decreased ability to walk any distance, as well as asymmetries in gait would rank highly import among these factors. Subjects studied were 18 women with modest signs of knee osteoarthritis, who were ambulatory without aids and not currently receiving any therapy.

The women were examined separately from men, as they may have differing disease manifestations that cause them to suffer more from this condition than men [5], especially with regards to gait and the pain experience. Although sampling issues and sample sizes are obvious limitations, the study objective was to assess overall personal estimates of disease impact and what remediable factors might predict this. Based on pilot work, the study was deemed to have sufficient power to demonstrate salient relationships between the impact scores and other variables examined, if these existed, and to establish if there would be possible trends in the impairment experience worthy of future exploration. A single measure of overall impact was selected for study to represent the perceived cumulative disability of the many systems problems encountered by the patient with this condition, and it was assumed to be a valid indicator of overall disease impact. Although only cases with mild symptoms were studied, it was felt important to examine the characteristics of these women to elucidate factors that could help to better understand to what degree the disease can impact perceived wellbeing and how these perceptions might be partially determined by clinical parameters such as walking rate and

gait asymmetry.

All subjects had radiographic and clinically verifiable disease as identified by a physician of one or both knees, and although age is often assumed to be determinant of osteoarthritis disability, age in this analysis yielded no significant overall relationship to the perceived impact of the disease on the wellbeing of the cohort, a subjective measure consistently linked to pain and physical functioning.

However, among the sample studied, the strongest mobility predictor of impact, regardless of any other factor was the measure of absolute stride length recorded electronically while walking at self-paced walking speed. That is, a shorter stride length correlated with worse scores on the arthritis impact scale. This factor was also related to the distance walked during a six minute period, and walking velocity, and suggests when women with knee osteoarthritis perceive their gait is less efficient than desirable, a more negative disease impact is perceived.

In addition, those that exhibited longer gait cycle durations, as well as more gait asymmetry when the stance duration for both legs was analyzed experienced more severe or adverse self-assessments of impact. Thus our data are not unlike those generated almost 15 years ago By Alzahara and Bakheit [29], who found cases with severe knee osteoarthritis had compromised walking ability, specifically, stride length was shorter and gait velocity was slower.

Earlier, Berman et al. [30] had drawn attention to the presence of similar abnormalities in a cohort that was marginally impaired. Yet, although Worsely et al. [31] found pre surgical joint loading asymmetry persisted among cases with knee osteoarthritis who underwent surgery, as did Thewlis et al. [32], a review of the literature reveals very little is often done for adults with non-severe knee osteoarthritis, as far as acknowledging and treating intra and interlimb asymmetries and their related causes, even if these appear to be etiologic factors as implied by Milner et al. [33] and Miller et al. [34]. For example women in this exploratory study-were not exposed to any form of remediation at the time of the conducted assessments, even though most had some functional challenges, even if these were minor, and some had marked discomfort and limited weight bearing capacity. As well, even if a small percentage stated the disease had no effect on their wellbeing, the entire cohort without exception failed to function at the same level as

healthy women, when taking the measured gait variables into account, and clearly showed the presence of interlimb asymmetry, which could be creating a mechanical problem that results over time in either bilateral joint disease in unilateral cases or more severe joint disease, regardless of whether the problem is unilateral or bilateral to start with. Moreover, the impact was greater for those with higher weights, and those with higher perceived disease impact, may be those who are more reluctant to carry out weight bearing activities including exercise, perhaps because of instability, muscle dysfunction, inflammation and pain, resulting in a downward spiral of mechanically inefficient events.

Given that walking is an activity subject that is amenable to very detailed analysis and improvement, and that reduced functional performance in the lower extremity including walking predicts radiographic knee osteoarthritis later on [12,35,36], we feel the results here, while limited in scope, have definite implications for practitioners who wish to reduce the immense knee osteoarthritis burden, subject of course to future confirmatory studies. In particular, since local mechanical stress at the knee is strongly implicated in the disease process, the bi-directional relationship between perceived global impact and gait asymmetry and stride length strongly suggests improvements in both realms might prove highly beneficial. Moreover, even if surgery is eventually required, outcomes may be more beneficial than not.

In particular, efforts to maximize stride length capacity, and to minimize interlimb gait parameter differences may help lessen the perceived impact of the condition. In turn, improving ambulatory ability may heighten life quality in cases with knee osteoarthritis, as well as allaying disease progression, while promoting more successful surgical outcomes among similar women, if this is desired. Indeed, given that middle-aged adults with arthritis are at high risk for developing mobility and activities of daily living difficulties that place them at an increased risk of obesity, and poor overall health outcomes, it would appear especially valuable to routinely employ more sophisticated approaches such as electromyography, intersegmental dynamic motion capture approaches, joint kinematic and kinetic tests, along with proprioception tests, tests of balance capacity, ligamentous stability, bilateral leg length measures, joint inflammation, locomotive syndrome tests [12], and muscle

strength and endurance measures at the outset of any initial consultation, and to examine this data carefully so as to not neglect important remediable determinants of this condition.

Since the most suitable form of conservative therapy for adults diagnosed as having knee osteoarthritis remains unknown, carefully designed gait analyses and appropriate interventions to maximize gait efficiency are is likely to help avert or minimize predictable cycles of pain and disability attributable to gait abnormalities. In our view, the majority of patients with modest knee osteoarthritis, as well as those with more severe disease, are likely to benefit from efforts to improve gait biomechanics and walking capacity, while reducing or delaying the need for surgery.

References

1. Palazzo C, Nguyen C, Lefevre-Colau MM *et al.* Risk factors and burden of osteoarthritis. *Ann. Phys. Rehabil. Med.* 59, 134-138 (2016).

1. Dillon CF, Rasch EK, Gu Q *et al.* Prevalence of knee osteoarthritis in the United States: arthritis data from the Third National Health and Nutrition Examination Survey 1991-94. *J. Rheumatol.* 33, 2271-2279 (2006).

1. Sissons HA. Osteoarthritis of the knee: A review. *J. Rheumatol.* 10, 76-77(1983

2. Felson DT, NaimarkA, Anderson JL *et al.* (1987) The prevalence of knee osteoarthritis in the elderly. *Arthritis. Rheum.* 30, 914-918.

1. Blagojevic M, Jinks C, Jeffery A *et al.* Risk factors for onset of osteoarthritis of the knee in older adults: a systematic review and meta-analysis. *Osteoarthritis. Cart.* 18, 24-33 (2010).

1. Phinyomark A, Osis ST, Hettinga BA *et al.* Gender differences in gait kinematics for patients with knee osteoarthritis. *BMC Musculoskelet. Disord.* 17, 157 (2016).

1. Hochberg MC, Lawrence RC, Everett DF *et al.* Epidemiologic associations of pain in osteoarthritis of the knee: data from the National Health and Nutrition Examination Survey and the National Health and Nutrition Examination-I Epidemiologic Follow-up Survey. *Semin. Arthritis. Rheum.* 18, 4-9 (1989).

1. Veronese N, Cereda E, Maggi S *et al.* Osteoarthritis and mortality: A prospective cohort study and systematic review with meta-analysis. *Semin. Arthritis. Rheum.* 46, 160-167 (2016).

2. Gupta S, Hawker GA, Laporte A *et al.* The economic burden of disabling hip and knee osteoarthritis (OA) from the perspective of individuals living with this condition. *Rheumatol.* 44, 1531-1537 (2005).

1. Rosemann T, Laux G, Szecsenyi J. Osteoarthritis: quality of life, comorbidities, medication and health service utilization assessed in a large sample of primary care patients. *J. Orthop. Surg.* 2, 12 (2007).

1. Sharma L, Cahue S, Song J *et al.* Physical functioning over three years in knee osteoarthritis: role of psychosocial, local mechanical, and neuromuscular factors. *Arthritis. Rheum.* 48, 3359-3370 (2003).

2. Ohsawa T, Yanagisawa S, Shiozawa H *et al.* Relationship between knee osteoarthritis and the locomotive syndrome risk tests:a cross-sectional study. *J. Orthop. Sci.* 21, 512-516 (2016).

3. Wilcox S, Brenes GA, Levine D, Sevick MA, Shumaker SA, et al. (2000) Factors related to sleep disturbance in older adults experiencing knee pain or knee pain with radiographic evidence of knee osteoarthritis. J Am Geriatr 48: 1241-1251.

1. Huang KH, Hsieh RL, Lee WC. Pain, physical function, and health in patients with knee osteoarthritis. *Rehabil. Nurs.* (2015).

2. Liu Y, Zhang H, Liang N *et al.* Prevalence and associated factors of knee osteoarthritis in a rural Chinese adult population: an epidemiological survey. *BMC Public. Health.* 16, 94 (2016).

3. de Kruijf M, Verlinden VJ, Huygen FJ *et al.* Chronic joint pain in the lower body is associated with gait differences independent from radiographic osteoarthritis. *Gait. Posture.* 42, 354-359 (2015).

1. O'Connell M, Farrokhi S, Fitzgerald GK. The role of knee joint moments and knee impairments on self-reported knee pain during gait in patients with knee osteoarthritis. *Clin. Biomech.* 31, 40-46 (2015).

2. Gustafson JA, Gorman S, Fitzgerald GK *et al.* Alterations in walking knee joint stiffness in individuals with knee osteoarthritis and self-reported knee instability. *Gait. Posture.* 43, 210-215 (2016).

3. Sutbeyaz ST, Sezer N, Koseoglu BF *et al.* Influence of knee osteoarthritis on exercise capacity and quality of life in obese adults. *Obesity.* 15, 2071-2076 (2007).

4. Bookwala J, Harralson TL, Parmelee PA. Effects of pain on functioning and wellbeing in older adults with osteotarthritis of the knee. *Psychol. Aging.* 18, 844-850 (2003).

5. Shi D, Dai J, Xu Z *et al.* Update on basic and clinical aspects of Osteoarthritis. Ann Transl Med 3, 142 (2015).

6. Peters TJ, Sanders C, Dieppe P *et al.* Factors associated with change in pain and disability over time: a community-based prospective observational study of hip and knee osteoarthritis. *Br. J. Gen. Pract.* 55: 205-211(2005).

7. Marcum ZA, Zhan HL, Moore CG, et al. Correlates of gait speed in advanced knee osteoarthritis. *Pain. Med.* 15, 1134-1342 (2014).

8. Fernandes WC, Machado A, Borella C *et al.* Influence of gait speed on plantar pressure in subjects with unilateral knee osteoarthritis. *Rev. Bras. Reumatol.* 54: 441-445 (2014).

1. Altman R, Asch E, Bloch G *et al.* Development of criteria for the classification and reporting of osteoarthritis. *Arthritis. Rheum.* 29, 1039-1049 (1986).

1. Meenan RF, Mason JH, Anderson JJ *et al.* AIMS2. The content and properties of a revised and expanded Arthritis Impact Measurement Scales Health Status Questionnaire. *Arthritis. Rheum.* 35, 1-10 (1992).

1. Liikavainio T, Isolehto J, Helminen HJ *et al.* Loading and gait symmetry during level and stair walking in asymptomatic subjects with knee osteoarthritis: importance of quadriceps femoris in reducing impact force during heel strike? *Knee.* 14, 231-238 (2007).

1. Block JA, Shakoor N. Lower limb osteoarthritis: biomechanical alterations and implications for therapy. *Curr. Opinion. Rheumatol.* 22, 544-550 (2010).

1. Al-Zahrani KS, Bakheit AM. A study of the gait characteristics of patients with chronic osteoarthritis of the knee. *Disabil. Rehabil.* 24, 275-280 (2002).

2. Berman AT, Zarro VJ, Bosacco SJ *et al.* (1987) Quantitative gait analysis after unilateral or bilateral total knee replacement. *J. Bone. Joint. Surg. Am.* 69, 1340-1345 (2002).

3. Worsley P, Stokes M, Barrett DS *et al.* Joint loading asymmetries in knee replacement patients observed both pre- and six months post-operation. *Clin. Biomech.* 28, 892-897 (2013).

4. Thewlis D, Hillier S, Hobbs SJ *et al.* Preoperative asymmetry in load distribution during quiet stance persists following total knee arthroplasty. *Knee. Surg. Sports. Traumatol. Arthrosc.* 22, 609-614 (2014).

5. Milner CE Interlimb asymmetry during walking following unilateral total knee. Arthroplasty. *Gait. Posture.* 28, 69-73(2008).

6. Mills K, Hettinga BA, Pohl MB *et al.* Between-limb kinematic asymmetry during gait in unilateral and bilateral mild to moderate knee osteoarthritis. *Arch. Phys. Med. Rehabil.* 94, 2241-2247 (2013).

7. Thorstennson CA, Petersson IF, Jacobsson LTH *et al.* Reduced functional performance in the lower extremity predicted radiographic knee osteoarthritis five years later. *Ann. Rheum. Dis.* 63, 402-407 (2004).

8. Miyazaki T, Wada M, Kawahara H *et al.* Dynamic load at baseline can predict radiographic disease progression in medial compartment knee osteoarthritis. *Ann. Rheum. Dis.* 61, 617-622 (2002).