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Gait Parameters in Different Knee Osteoarthritis Radiological Grades

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Abstract

Background: Osteoarthritis (OA) is one of the most prevalent condition resulting to disability particularly in elderly population. Gait changes in knee OA has been explored but there are no previous studies establishing the relationship of these gait parameter changes with increase in radiological grade of OA. Research Question: Does the spatiotemporal parameters changes consistently with increase in radiological grade in patients with OA knee?

Method: A total of 96 subjects, 24 subjects each from Kellgren-Lawrence grade 1 to 4, with bilateral medial compartment knee OA and age group 40-70 years, fulfilling inclusion and exclusion criteria were enrolled. Gait analysis was done for all subjects with the same protocol at a self-selected walking speed. Gait parameters were measured for each subject which included cadence [steps/min], speed [m/s], mean stride length [m], normalised stride length [% height], stance phase duration [%], swing phase duration [%], single support phase [%] and 1st double support phase [%].

Result: There was a progressive decrease in cadence, walking speed, mean stride length, normalised stride length, swing phase duration and single support phase, with a progressive increase in stance phase duration and 1st double support phase with increase in grade of OA. All the above parameters except mean swing phase duration were observed to have a significant change with increase in grade of OA. In conclusion, the changes in spatiotemporal gait parameters in patients with OA knee, appears to be consistent with the disease progression. Significance: Rehabilitation strategies for knee OA can be directed towards interventions addressing the gait changes and treatment effects can be monitored effectively with gait analysis because of the consistency in gait changes with increase in radiological grade.

Keywords: Osteoarthritis; Spatiotemporal gait parameters; Radiological Grade; Rehabilitation strategies

Abbreviations: OA: Osteoarthritis; K-L Kellgren-Lawrence; P: Probability.

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Introduction

Osteoarthritis (OA) is one of the most prevalent disease resulting to disability particularly in elderly population. OA is the most common articular disease of the developed world and a leading cause of chronic disability, mostly as a consequence of the knee OA and/or hip OA [1]. Knee OA is more important not only for its high prevalence rate compared with other sites but also for its presentation at earlier age groups particularly in younger age groups of obese women.

The incidence of knee OA increases by age and further increase with higher average weight of the population [2]. Gait analysis has become an important tool for quantifying normal and pathological walking patterns and has been suggested to be useful for selecting treatment options and evaluating their results, as well as identifying responders to specific interventions [3-5]. Spatiotemporal parameters are considered to be important parameters of gait in knee OA which is quite easy to evaluate and less time consuming and these may be good predictors of disability [6].

Properly designed cross-sectional studies on gait changes in different radiological grades of knee OA can provide an important insight into the changing role of biomechanical factors and important gait adaptations by the patient throughout the progression of the disease. Understanding gait characteristics of individuals early in the OA disease process provides potential for developing non-surgical interventions to reduce pain and slow the disease progression. In regard to gait, compared to matched controls, knee OA patients have reductions in walking speed [7-9] and cadence [10], longer double support time [11] and a smaller stride length [12].

While knee OA has been shown to affect a multitude of kinematic, kinetic and spatiotemporal gait parameters, few investigators have examined the effect of increasing levels of radiographic OA severity on these gait parameters [13,14]. Furthermore, no such study to our knowledge has been done on Indian population. Moreover, study populations have typically been small [15-17]. In addition, knee OA has been used as a generic inclusion criterion [9,10,17-20] and no distinction was made between patients with OA affecting the medial knee compartment and those with OA in the lateral compartment. The objective of our study was to determine the influence of increasing radiological grades of knee OA on the spatiotemporal gait parameters in patients with bilateral medial compartment OA knee. We hypothesized that there is some change in various gait parameters with increasing radiological grade of knee OA.

Material and Methods

Subjects and selection

This observational study was conducted at Department of Physical Medicine and Rehabilitation, King George's Medical University, Lucknow, India, of duration 12 months from September 2017 to August 2018. A total of 96 patients with primary bilateral medial compartment OA knee, 24 each from Kellgren-Lawrence (K-L) grade 1 to 4 [21] were included in the study who met inclusion and exclusion criteria. Inclusion criteria were radiographic evidence of bilateral medial compartment knee OA (KL grade 1-4), ambulatory without the use of an assistive device, patients who were able to walk 11 meters repeatedly and age between 40–70 years. The detailed exclusion criteria are shown in Table 1. The Institutional Ethical Committee approved the study design.

Exclusion criteria of the knee OA subjects.
• A history of previous fracture or other significant injury of hip, knee or pelvic region
• Surgery of the lower extremities except knee arthroscopy
• Surgery of the vertebral column
• A clinical or radiological hip OA
• A knee or hip joint infection
• Congenital or developmental disease of lower limbs
• Paralysis of lower extremities
• Any disease or medication that might have worsened physical function and interfered with the Evaluation of knee pain, such as:
• Malignancy
• Psychiatric illness
• Rheumatoid arthritis or spondyloarthropathies
• Symptomatic cerebrovascular disease
• Recent intra-articular injection in knee
• Parkinson's disease

• Polyneuropathies • Debilitating cardiovascular disease in spite of medication • Vascular/neurological claudication • Low back pain

Table 1: Exclusion Criteria.

Radiographic assessment

Weight bearing anterior-posterior and medial-lateral radiographs were taken from both knees. The classification was done based on anterior– posterior tibio-femoral radiographs using the KL grading scale (0–4), in which grade ≥1 was regarded as knee OA. Subjects were further divided into four subgroups (Grade 1–4) according to KL scale classification.

Gait analysis

All study participants walked barefoot along a defined 11-meter walk-way in the gait and motion analysis laboratory (BTS motion analysis LAB, BTS Bioengineering, USA, 2009 Spa®), at a comfortable, self-selected speed. The subjects were instructed to walk naturally at a steady speed. Spatiotemporal parameters were collected using the WALK protocol of BTS G-WALK. Components of BTS G-WALK include a wireless inertial sensor, belt (+ extension), Bluetooth dongle, USB charge cable, G-Studio Software and transport bag (figure1).

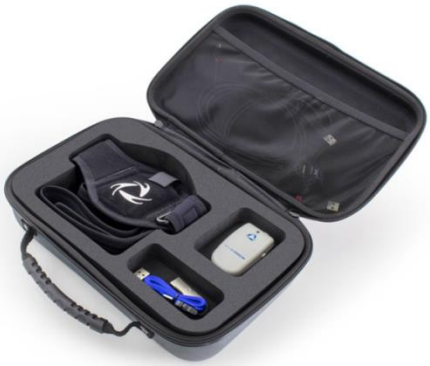

Figure 1: BTS G-WALK kit.

BTS G-SENSOR is a wearable inertial sensor allowing acquiring and transmitting data to the PC through a Bluetooth connection and BTS G-STUDIO is the advanced software for the management of the patient database, data acquisition, elaboration, and reporting. The sensor was placed firmly in place on the lower back near the body's centre of mass, by inserting it in the specific pocket of the belt, with the power supply connector placed upward and logo facing out, paying attention in positioning it as vertical as possible (Figure2).

Figure 2: Sensor positioning.

The "Walk" protocol for the Gait analysis provides all the spatiotemporal gait parameters and the kinematics of the pelvic girdle. The software automatically recognizes the discontinuity points in the recorded path and will eliminate the corresponding strides from the analysis. To ensure that the gait analysis will be correctly performed, we recommended registering at least 5 complete strides per side. Before starting the recording it was necessary to instruct the subject of how to perform the trial. Once the subject was ready and standing in orthostatic position, the acquisition process was activated. Patient was asked to hold the orthostatic standing position for the whole duration of the stabilization phase. After completion of the acquisition phase, the test was done by the defined protocol.

Spatiotemporal Parameters Collected:

- Cadence (steps/min): Number of steps in a minute.
- Speed (metres/second): Average walking speed.
- Mean stride length (metres): Average value of distances between each initial contact and the next one of same side.
- Normalised stride length (% height): Stride length normalized over the height of the subject.
- Stance phase duration (% gait cycle): Average value of the duration of the right and left foot support phase as percentage of the gait cycle.

- Swing phase duration (% gait cycle): Average value of the duration of the right and left swing phase as percentage of the gait cycle.
- Single support phase (% gait cycle): Duration of the phase in which only one foot is in stance position as percentage of the gait cycle.
- First double support phase (% gait cycle): Duration of the double support phase (in which both foot are in stance position as percentage of the gait cycle) that occurs at initial contact phase.

Statistical analysis

The data was analysed using PASW statistics 24.0 (SPSS Inc., Chicago, IL). Demographic statistics as well as spatiotemporal parameters in the four grades of OA were calculated using mean and standard deviation. Two tailed Probability (p) was calculated to test statistical significance at the 5% level of significance. One-way Annova test was used to compare mean value of spatiotemporal gait parameters across the four grades of OA. Spearman correlation test was used to determine the strength of relationship between changes in gait parameters and increase in grade of OA.

Results

A total of 96 patients with bilateral medial compartment OA knee were enrolled and equally distributed with 24 patients each in K-L grade 1-4 respectively. All results are summarized in Tables 2 and 3.

Parameters	1	2	3	4	p-value
Age (years)	52.4±11.5	52.6±9.1	55.7±11.6	58.2±8.1	0.159
Male (%)	22.2	29.6	25.9	22.2	0.958
Female (%)	18	16	17	18	
Body Mass Index (BMI) (Kg/m^2)	26.4±4.5	26.6±4.3	27.4±5.2	27.9±5.1	0.766
Cadence (steps/min)	107.32±7.64	100.61±6.29	99.66±3.44	92.09±12.00	0.0001*
Speed (m/s)	0.995±0.12	0.931±0.11	0.918±0.11	0.752±0.12	0.0001*
Mean stride length (m)	1.12±0.14	1.12±0.12	1.09±0.16	0.98±0.13	0.003*
Mean % stride length(%height)	71.17±9.24	69.93±8.04	68.78±8.73	62.17±8.67	0.003*
Mean stance phase duration (%cycle)	61.62±1.97	62.09±2.51	62.95±1.71	63.98±3.48	0.009*
Mean swing phase duration (%cycle)	38.38±1.97	37.90±2.52	37.42±2.06	36.71±3.53	0.154
Mean first double support phase (%cycle)	12.97±1.48	14.99±2.64	16.45±2.80	19.12±4.05	0.0001*
Mean single support phase (%cycle)	36.77±1.33	35.03±2.54	32.95±3.16	31.31±3.55	0.0001*

* $p<0.01$, highly significant

Table 2: Demographic characteristics and the spatiotemporal parameters of patients with K-L grade 1-4.

Parameter	Correlation Coefficient#	p Value
Mean Stride Length (M)	-0.334	0.001*
Mean Normalised Stride Length (%Height)	-0.351	0.0001*
Mean Stance Phase Duration (%Cycle)	-0.264	0.009*
Mean Swing Phase Duration (%Cycle)	-0.197	0.054
Mean First Double Support Phase (%Cycle)	0.609	0.0001*
Mean Single Support Phase Duration (%Cycle)	-0.599	0.0001*
Cadence (Steps/Minute)	-0.507	0.0001*
Speed (Metres/Sec)	-0.563	0.0001*
Mean Stride Length (M)	-0.334	0.001*
Mean Normalised Stride Length (%Height)	-0.351	0.0001*
Mean Stance Phase Duration (%Cycle)	-0.264	0.009*

Mean Swing Phase Duration (%Cycle)	-0.197	0.054
Mean First Double Support Phase (%Cycle)	0.609	0.0001*
Mean Single Support Phase Duration (%Cycle)	-0.599	0.0001*
Cadence (Steps/Minute)	-0.507	0.0001*
Speed (Metres/Sec)	-0.563	0.0001*

#spearman correlation, *p<0.01, highly significant
Table 3: Correlation of spatiotemporal parameters with OA knee grade

There were no statistically significant differences in demographic variables of patients including age, sex, and BMI in all four groups. There was a progressive decrease in cadence, walking speed, mean stride length, normalised mean stride length, swing phase duration and single support phase with increase in grade of OA. All the above results were statistically significant except mean swing phase duration. Similarly there was a progressive increase in stance phase duration and double support phase with increase in radiological grade and the results were found to be statistically significant. Also the strength of correlation for all spatiotemporal
parameters with grades of OA knee were found to be statistically significant except for mean swing phase duration.

Discussion

The objective of the present study was to determine the influence of increasing radiological grades of knee OA on the spatiotemporal gait parameters in patients with bilateral medial compartment knee OA. According to Borjesson et al., the spatiotemporal parameters of gait are those most directly influenced by the severity of the pathology or of the treatment done [22]. Assessment of gait changes should be helpful in determining the occurrence of adaptive mechanisms during the course of knee OA.

There was a female preponderance in our study population (71.9%), as prevalence of knee OA is considered to be more in females. A study conducted on Indian population by Sharma et al. [23], also had female preponderance (73%) which is very similar to our study. Also, most of the subjects were overweight (41.6%) or obese (23.9%), as obesity is considered a risk factor for the development of knee OA [24]. In a systematic literature search obesity was consistently the main factors with knee OA by OR 2.63 [25].

There was a progressive decrease in cadence, walking speed, mean stride length, normalised mean stride length, swing phase duration and single support phase with increase in grade of OA. All the above parameters except swing phase duration had a statistically significant decrement with increase in grade of OA. This is in accordance with findings of several previous studies showing a decrease in cadence in OA knee patients [6,15,26]. In several past studies, self-selected walking speed has been reported to decrease in patients with OA knee [7,15,26,27].

Previous studies also suggest a reduced mean stride length and normalised mean stride length in patients with OA knee [6,15,17,26,27]. A reduced mean single support phase in this study is supported by Chen et al. [28]. According to Andriacchi et al. [29], reduced walking speed and stride length were part of the adaptive mechanism to reduce pain by decreasing knee moments. According to Prodromos et al. [30], a reduced stride length suggest an unloading mechanism during gait which appears to be beneficial in patients with medial compartment OA knee, which could be a protective mechanism against further progression of the disease by resisting the external adduction moment. Mundermann et al. demonstrated that patients with knee OA, more effectively in those with higher grades, reduce velocity for reduction of the knee adduction moment [31].

In this study, there was a progressive increase in stance phase duration and first double support phase with increase in grade of OA and both of these findings were statistically significant. Above findings are supported by several past studies showing a longer stance phase duration [15,27,32] and a longer double support phase [9,11,15] in patients with OA knee. These changes may also be indicative of adaptations to the abnormal knee joint loading caused by OA knees. Another possible explanation for the observed gait differences between different grades is the difference in self-selected speed of walking. Also among others are decreased joint mobility, reduced muscle strength, and impaired proprioception all of which might have contributed to altered gait characteristics especially in the elderly patients with knee OA [33].

This study can't determine whether the gait pattern differences are the result, or a contributing factor, of knee OA. There is a need for further work examining differences in gait across the spectrum of disease severity.

Furthermore, the gait differences observed in this study may have been affected by differences in walking velocity. At issue is the fact that the effect of speed on gait mechanics is not fully understood. Also because of high cost and time constraint of the study we didn't evaluate the changes in ground reaction force, kinetic and kinematic parameters, and muscle activation patterns, which are much important parameters of gait. Although the results of this study are encouraging, relatively few patients were evaluated to serve as a basis for broad clinical conclusions at this time. Therefore, longitudinal studies with larger groups are needed to support our findings.

Conclusion

In conclusion, the changes in spatiotemporal gait parameters in patients with OA knee, appears to be consistent with the disease progression. Assessment of gait changes at an early stage of OA knee should be helpful in distinguishing between abnormalities causing progression of the disease and occurring as a part of the compensatory mechanism during the course of the disease. We recommend rehabilitation strategies to be directed towards interventions addressing gait dysfunction effectively and future studies should incorporate an objective gait analysis to examine and monitor various treatment effects compared to matched controls.

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Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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