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ORIGINAL ARTICLE

Gait Analysis and Functional Knee Scores in Primary Knee Osteoarthritis and Their Correlation with Progression of the Disease in the Indian Population

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Abstract

Introduction Osteoarthritis of the knee is a leading cause of disability and is a multi-factorial disease. Moreover, it is partly considered a mechanically driven disease in which higher abnormally disbursed forces play a prime role. With the progression of the disease, the gait function declines, so a comprehensive and objective evaluation of gait function would help in prognostic evaluation and management.

Materials and Methods This study included two groups: patients with primary knee osteoarthritis and a control group of healthy volunteers. Gait analysis and functional knee scores were evaluated for all the subjects. The KOOS score, temporal parameters excluding the step length, and spatial parameters excluding the stance phase percentage were evaluated for an individual as a whole. The KSS score, kinetic parameters, kinematic parameters, step length, and stance phase percentage were calculated for each knee separately. Each knee of the patient and controls was taken as 1 sample and categorized as per Kellgren–Lawrence score. An asymptomatic control group of subjects were included in group A. Symptomatic patients with KL grades 1, 2 were included in group M, and those with KL grades 3, 4 were included in group S. The kinetic and kinematic parameters and KSS score were compared among the three groups.

Results A total of 60 subjects were included of which 40 were patients and 20 were controls. In the control group, the age ranged from 22 to 48 years with a mean age of 28.6 years. In the patient group, the mean age was 60.3 years. Patients with knee osteoarthritis were significantly obese with slower walking speed, short stride length, longer stride time, and decreased cadence compared to the asymptomatic group. There was a significant difference in spatiotemporal parameters, functional scores, and kinetic and kinematic parameters among the groups.

Conclusion Various spatiotemporal, kinetic, and kinematic parameters like peak knee flexion angle, abduction/adduction angle, peak knee adduction moment, range of knee flexion, peak knee flexion, and gait deviation index along with functional scores varied significantly with the progression of the disease.

Keywords Knee osteoarthritis · Gait analysis · Patient-reported outcome measures · Knee adduction moment · Gait profile score · Gait deviation index

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Introduction

Osteoarthritis (OA) is a leading cause of disability. More than 260 million people suffer from OA worldwide [1]. The main characteristics of knee osteoarthritis (KOA) are pain and gait dysfunction, which gets worse as the stage of KOA progresses [2].

During normal ambulation in healthy knees, the medial compartment experiences 60–80% of the weight-bearing load. Knee malalignment that places the joint in a varus position can increase loading on the medial side of the joint. Moreover, the degeneration of the joint during the progression of KOA can also cause an increase in varus malalignment. The knee adduction moment (KAM) describes the load distribution across the medial and lateral tibial plateaus. Increasing the KAM has been associated with the progression and possibly the initiation of knee OA [3]. KOA disease severity is often evaluated by plain radiographs [4–6].

Gait analysis can objectively evaluate gait dysfunction in individuals with joint disease, including KOA [7]. Several features are correlated with KOA severity [2, 8]. Kinematic variables associated with the development, progression, and severity of knee OA are the knee adduction moment (KAM) and tibiofemoral rotation. Due to its strong correlation with disease progression and pain, the peak KAM during gait has been identified as a target for treatment design [3]. Spatiotemporal gait parameters, including speed, cadence, and duration of the stance phase, differ significantly in KOA patients and asymptomatic groups [9].

Various approaches can be used to represent different gait features in KOA. In OA, the gait features with great significance in the proper detection of the disease are Knee Flexion Moment (KFM), Knee Flexion Angle (KFA), speed, stance and swing time, etc. From gait analysis, different gait features can be identified and used, which are divided into anthropometric, spatiotemporal, silhouette, kinetic, kinematic, and hybrid [10].

With the progression of the disease, the gait function declines, so a comprehensive and objective evaluation of gait function would help in prognostic evaluation and management. Moreover, the assessment of physical function in OA is complex, so performance-based measures and patient-reported outcome measures (PROM) of knee function and pain are recommended as they represent complementary and different constructs of physical functioning [11, 12].

Methodology

This prospective study was conducted after getting approval from the institutional review board and ethics committee (IECPG-701/23.12.2020). This study included two groups: patients with primary knee osteoarthritis and a control group of healthy volunteers.

Control Group

Asymptomatic volunteers more than 18 years of age without any complaints of low back pain, hip and knee pain, and no contraindication for radiographic exposure were included in this study.

Patient Group

Inclusion Criteria

All patients of primary osteoarthritis of the knee of age > 50 years who visited our orthopedics department.

Exclusion Criteria

Patients with post-traumatic osteoarthritis, inflammatory arthritis, and a history of previous surgical procedures on the spine or bilateral lower limb were excluded. Patients using any walking aid for ambulation were also excluded.

For all the patients and controls included in this study, history was obtained and a detailed examination was done. Their details of height, weight, and BMI were recorded. This was followed by a radiographic assessment for subgrouping based on the Kellgren–Lawrence classification. The functional assessment was done with KOOS and KSS scores for symptomatic patients. All the patients and controls underwent gait analysis and gait parameters were evaluated.

Radiographic Assessment

Standing anterior–posterior and lateral view X-rays of the knee were taken and severity was assessed according to the Kellgren–Lawrence classification [13].

Gait Assessment

Gait Protocol for Marker Placement

Helen Hayes protocol was used to evaluate the lower limbs, pelvis, and trunk movements during gait [14]. Using this method, a report was generated including spatiotemporal parameters, joint kinematics, and kinetics evaluated during the different phases of the gait cycle.

Gait Data Recording

The subject was asked to stand on the force plate in a steady state for 5 s to capture standing angles and ground reaction forces. Left and Right ground reaction forces were marked. The subject was allowed to walk barefoot in the calibrated area at their self-selected comfortable walking speed. Four to five walking frames were recorded, and the best walking frame based on the force vector generated on the force plate was used for data processing.

Gait Parameters

Temporal Parameters

Stride time(s), stance time(s), swing time(s), stance phase (%), swing phase (%), mean velocity (m/s), mean velocity (%height/s), and cadence (steps/min) were measured.

Spatial Parameters

Stride length (m), stride length (% height), step length (m), and step width (m) were measured.

Kinematic Measurements

3D shoulder, pelvis, and lower limb motions were measured using 18 reflective markers tracked by twelve infrared cameras, using SMART-clinic software (BTS, Italy).

Knee flexion–extension (degree), knee valgus-varus (degree), and knee rotation (degree) were measured. Gait profile score and the gait deviation index were recorded.

Kinetic Measurements

Knee moment (N*m/kg) was measured using force platforms (BTS, Italy).

The KOOS score, temporal parameters excluding the step length, and spatial parameters excluding stance phase % were evaluated for an individual as a whole and hence were compared between patients and controls. The KSS score, kinetic parameters, kinematic parameters, step length, and stance phase % were calculated for each knee separately. Each knee of the patient and controls was taken as 1 sample and categorized as per Kellgren–Lawrence score. The individual knees were grouped into three groups as per the Kellgren–Lawrence score:

Group A (Asymptomatic KL 0)
Group M (Mild KL 1, 2)
Group S (Severe KL 3, 4)

The kinetic parameters, kinematic parameters, step length and stance phase percentage, and KSS score were compared in 3 groups.

Statistical Analysis

The continuous variables obtained from the study were presented as mean (SD) or median (IQR) according to the distribution of the data. Categorical variables are presented as numbers and percentages. The D'Agostino-Pearson test was used to check the normal distribution of data. For parametric data, one-way ANOVA for three groups, and an unpaired *t*-test for comparison between control (C) and patient (P) was used and a *P* value less than 0.05 was taken as statistically significant.

For non-parametric data, the Kruskal–Wallis test for three groups and Wilcoxon rank sum for comparison between control (C) and patient (P) were used and a P value less than 0.05 was taken as statistically significant. Post hoc analyses (Conover and Scheffe test) for nor-parametric and parametric data were, respectively, used.

To evaluate the correlation for parametric data, Pearson product–moment correlation coefficient (r) and, for non-parametric data, Spearman's rank correlation coefficient (ρ) were used ($\pm$ 1 perfect correlation and 0 no correlation) [15].

Statistical software STATA (version 14.2, Stata Corp, Texas, USA) was used for all the analysis.

Results

Demography (Along with Height, Weight, and BMI) (Table 1)

A total of 60 subjects were included of which 40 were patients and 20 were controls.

Table 1 Demographic characteristics along with height, weight, and BMI of controls and patients

Characteristics	Controls (C)	Patients (P)
Age, mean [SD], years	28.6 [6.02]	60.3 [6.57]
Gender, *n* (%)		
Female	2 {10}	20 {50}
Male	18 {90}	20 {50}
Height, mean [SD], cm	170.75 [7.75]	157.42 [8.56]
Weight, mean [SD], kg	72.47 [15.11]	71.55 [11.50]
BMI, mean [SD], kg/m^3	24.59 [3.4]	28.75 [4.4]

In the control group, the age ranged from 22 to 48 years with a mean age of 28.6 years. In the patient group, the mean age was 60.3 years.

Spatiotemporal Parameters (Table 2)

There was a significant increase in stride time, stride length, and a significant decrease in cadence, mean velocity, and no significant difference in step width between the 2 groups.

Relationship of Radiographic Grades of Knee Osteoarthritis and 3D Gait Analysis

The groups as per Kellgren–Lawrence score are as follows:

Group A (asymptomatic KL score 0): 40 knee joints
Group M (mild KL scores 1, 2): 14 knee joints
Group S (severe KL scores 3, 4): 66 knee joints.

Functional Score and Spatiotemporal Parameters (Table 3)

There was a significant decrease in KSS (knee score) with the progression of disease severity. There was a significant decrease in step length between group A, group M, and group S, but a post hoc analysis showed that the difference was significant between group A versus M and A versus S, but no significant decrease between group M versus S. There was a significant increase in stance phase % between group A, group M, and group S, but a post hoc analysis showed that the difference was significant between group A versus M and A versus S, but no significant decrease between group M versus S.

Kinematic Parameters (Tables 3, 4)

The peak knee flexion angle (°) mean [± SD] for group A, group M, and group S was 62.85 [± 4.55], 56.37 [± 10.0], and 45.38 [± 15.65], respectively. The knee flexion angle range (°) mean [± SD] for group A, group M, and group S was 62.18[± 3.35], 49.85 [± 10.14], and 39.88 [± 16.74], respectively. The gait profile score (°) mean [± SD] for group A, group M, and group S was 6.36 [± 1.33], 9.52 [± 2.25], and 11.50 [± 3.01], respectively. The gait deviation index mean [± SD] for group A, group M, and group S was 94.164 [± 6.88], 81.44 [± 10.34], and 76.06 [± 10.56], respectively. The peak knee flexion angle till mid-stance median [IQR] for group A, group M, and group S was 17.85° [13.7–22.3], 17.60° [13.8–20.4], and 13.45° [4.3–18.9], respectively. The knee flexion angle at heel strike median [IQR] for group A, group M, and group S was 4.4° [1.7–8.7], 9.1° [4.1–9.1], and 7.15° [2.5–10.9], respectively. The abduction/adduction at heel strike median [IQR] for group A, group M, and group S was 6.1° [4.0–9.4], 10.65° [6.6–12.1], and 11.90° [8.9–17.3], respectively. The ROM of knee abduction/adduction median [IQR] for group A, group M, and group S was 14.90 [11.5–20.1], 12.00 [8.3–14.9], and 10.550 [6.3–17.7], respectively. The rotation at heel strike median [IQR] for group A, group M, and group S was – 10.0° [– 12.8 to (1.2)], – 5.25° [– 12.0 to (– 1.3)], and – 10.8° [– 18.1 to (– 2.5)], respectively.

Table 2 Spatiotemporal parameters of controls and patients

Spatiotemporal parameters	Controls (C) Mean [SD]	Patients (P) Mean [SD]	*P* value
Stride time (s)	1.08 [0.07]	1.39 [0.22]	< 0.001
Stride length (m)	1.29 [0.14]	0.80 [0.18]	< 0.001
Stride length(%height)	76.60 [6.22]	51.29 [10.64]	< 0.001
Step width	0.116 [0.05]	0.115 [0.04]	0.9
Cadence (steps/min)	110.68 [7.02]	88.56 [13.60]	< 0.001
Mean velocity (m/s)	1.21 [0.16]	0.61 [0.20]	< 0.001
Mean velocity (%height/s)	70.95 [8.81]	38.5 [12.47]	< 0.001

Table 3 Functional score, spatiotemporal parameters, kinetic parameters, and kinematic parameters of group A (asymptomatic), group M (mild: KL 1 + 2), and group S (severe: KL 3 + 4)

Parameter	Group A Mean [SD]	Group M Mean [SD]	Group S Mean [SD]	ANOVA *P* value (< 0.05)	Multiple comparison *P* value (Scheffe test) (< 0.05)		
					A versus M	M versus S	S versus A
KSS (knee score)	100 [0]	73.71 (16.20)	59.72 (12.9)	< 0.001	< 0.05	< 0.05	< 0.05
Step length (m)	0.64 [0.05]	0.44 [0.08]	0.39 [0.99]	< 0.001	< 0.05	> 0.05	< 0.05
Stance phase %	58.83 [2.68]	64.54 [4.4]	65.14 [5.33]	< 0.001	< 0.05	> 0.05	< 0.05
Peak Knee flexion angle (°)	62.85 [4.55]	56.37 [10.0]	45.38 [15.65]	< 0.001	> 0.05	< 0.05	< 0.05
Knee flexion angle range (°)	62.18 [3.35]	49.85 [10.14]	39.88 [16.74]	< 0.001	< 0.05	< 0.05	< 0.05
Gait profile score (°)	6.36 [1.33]	9.52 [2.25]	11.50 [3.01]	< 0.001	< 0.05	< 0.05	< 0.05
Gait deviation index	94.164 [6.88]	81.44 [10.34]	76.06 [10.56]	< 0.001	< 0.05	> 0.05	< 0.05
Peak knee adduction moment (Nm/kg)	0.56 [0.266]	0.808 [0.40]	0.74 [0.33]	0.01	> 0.05	> 0.05	< 0.05

Table 4 Kinematic parameters between group A (asymptomatic), group M (mild KL 1 + 2), and group S (severe KL 3 + 4)

Parameter	Group A Median [IQR]	Group M Median [IQR]	Group S Median [IQR]	Kruskal–Wallis test *P* value (< 0.05)	Post hoc analysis (Conover) P value (< 0.05)		
					A versus M	M versus S	S versus A
Knee flexion angle peak till mid-stance (°)	17.85 [13.7–22.3]	17.60 [13.8–20.4]	13.45 [4.3–18.9]	0.002	> 0.05	< 0.05	< 0.05
Knee flexion angle at heel strike (°)	4.4 [1.7–8.7]	9.1 [4.1–9.1]	7.15 [2.5–10.9]	0.118	> 0.05	> 0.05	> 0.05
Abduction/adduction at heel strike (°)	6.1 [4.0–9.4]	10.65 [6.6–12.1]	11.90 [8.9–17.3]	< 0.0001	< 0.05	> 0.05	< 0.05
ROM of knee abduction/adduction (°)	14.9 [11.5–20.1]	12.0 [8.3–14.9]	10.55 [6.3–17.7]	0.005	< 0.05	> 0.05	< 0.05
Rotation at heel strike (°)	− 10.0 [− 12.8 to (1.2)]	− 5.25 [− 12.0 to (− 1.3)]	− 10.8 [− 18.1 to (− 2.5)]	0.33	> 0.05	> 0.05	> 0.05

Kinetic Parameters (Tables 3, 5)

The peak knee adduction moment mean [± SD] for group A, group M, and group S was 0.56 [± 0.266], 0.808 [± 0.40], and 0.74 [± 0.33], respectively. The knee adduction moment mid-stance minimum median [IQR] for group A, group M, and group S was 0.269 Nm/s [0.184–0.401], 0.623 Nm/s [0.185–0.742], and 0.411Nm/s [0.289–0.610], respectively. The peak knee flexion moment median [IQR] for group A, group M, and group S was 0. 0.277 Nm/s [0.117–0.384], 0.133 Nm/s [0.032–0.213], and 0.103Nm/s [0.018–0.218], respectively. The knee flexion moment late stance minimum median [IQR] for group A, group M, and group S was − 0.386 Nm/s [− 0.511 to (− 0.186)], − 0.211 Nm/s [− 0.317 to (− 0.087)], and − 0.265 Nm/s [− 0.530 to (0.005)], respectively.

Relationship Between Gait Analysis and Functional Scores

In our study, we found that the knee flexion angle peak, the flexion angle range, and gait profile score significantly differed in group A (asymptomatic), group M (moderate KL grades 1,2), and group S (severe KL grades 3, 4). Here, we examined the relation of the 3 parameters with the KOOS and KSS functional scores.

The peak knee flexion angle had a good positive correlation with KOOS with Pearson product–moment correlation coefficient (r) being 0.575 ($P < 0.0001$) (Fig. 1a). The peak knee flexion angle had a good positive correlation with KSS with a Pearson product–moment correlation coefficient (r) was 0.637 ($P < 0.0001$) (Fig. 1b). The gait profile score had a high negative correlation with KOOS with Pearson product–moment correlation coefficient (r) being − 0.749 ($P < 0.0001$) (Fig. 1c). The gait profile score had a high negative correlation with KSS with Pearson product–moment correlation coefficient (r) was − 0.732 ($P < 0.0001$) (Fig. 1d).

Table 5 Comparison kinetic parameters between group A (asymptomatic), group M (mild KL 1 + 2), and group S (severe KL 3 + 4)

Parameter	Group A Median [IQR]	Group M Median [IQR]	Group S Median [IQR]	Kruskal–Wallis test P value (< 0.05)	Post hoc analysis (Conover) *P* value (< 0.05)		
					A versus M	M versus S	S versus A
Knee adduction moment mid-stance minimum (Nm/kg)	0.269 [0.184–0.401]	0.623 [0.185–0.742]	0.411 [0.289–0.610]	0.001	< 0.05	> 0.05	< 0.05
Peak knee flexion moment (Nm/kg)	0.277 [0.117–0.384]	0.133 [0.032–0.213]	0.103 [0.018–0.218]	0.0003	< 0.05	> 0.05	< 0.05
Knee flexion moment late stance minimum (Nm/kg)	− 0.386 [− 0.511 to (− 0.186)]	− 0.211 [− 0.317 to (− 0.087)	− 0.265 [− 0.530 to (0.005)]	0.049	< 0.05	> 0.05	< 0.05
Knee rotation moment peak (Nm/kg)	0.03 [0.022–0.066]	0.04 [0.007–0.07]	0.03 [0.013–0.062]	0.4	> 0.05	> 0.05	> 0.05

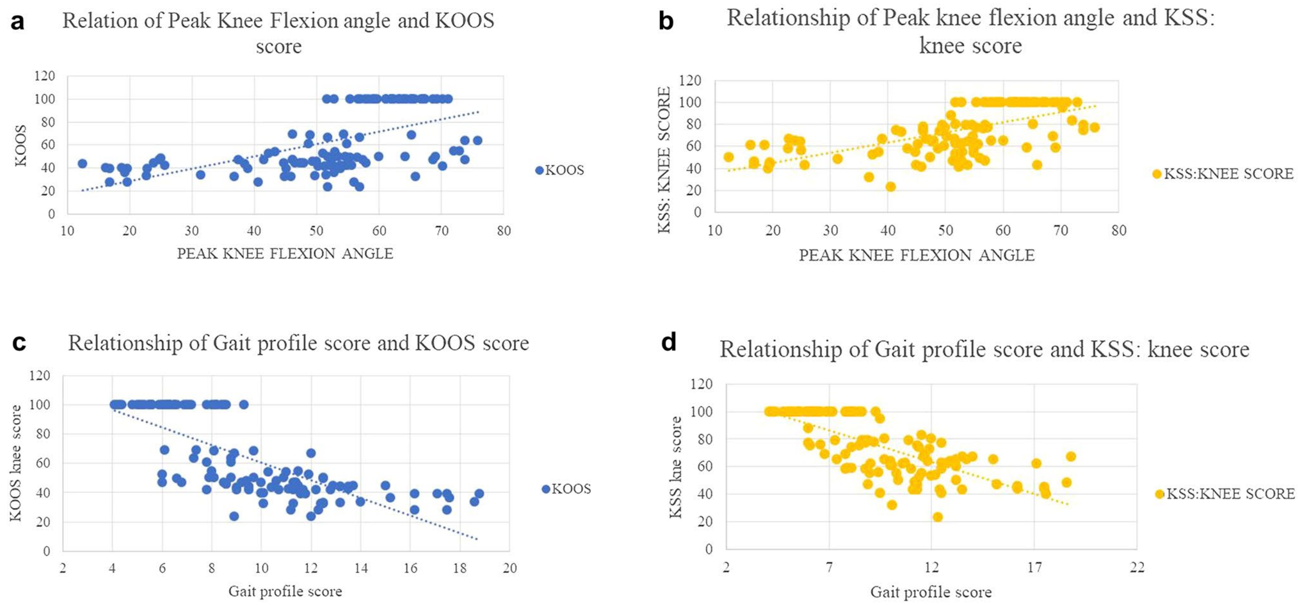

Fig. 1 **a** Relationship between peak knee flexion angle and KOOS score. **b** Relationship of peak knee flexion angle and KSS: knee score. **c** Relationship of gait profile score and KOOS score. **d** Relationship of gait profile score and KSS: knee score

Discussion

For KOA obesity is one of the most commonly identified risk factors [16]. The patient group's BMI was significantly higher than the control group in our study, similar to a study done by Astephen et al. [17] and Thorp et al. [18].

Similar to the study conducted by Rana et al. [19], our study had shown a significant decrease in stride length, step length, walking velocity, and cadence, and but in our study, we have not found a significant difference in step width between healthy controls and OA knee patients.

The KSS knee score decreased significantly with the progression of KOA (between the asymptomatic and mild group and from the mild to the severe group) in our study which was similar to the study by Oishi et al. [20].

The step length decreased significantly between asymptomatic and both KOA groups, but the decrease was not significant between the mild and severe groups. In a study by Rana et al. [19], the step length decreased significantly between asymptomatic and KOA patients.

The percentage of stance phase increased significantly between asymptomatic and both OA groups, but the increase was not significant between mild and severe groups, whereas in a study conducted by Astephen et al. [17], it increased with the progression of KOA.

In a study by Astephen et al. [17] the peak knee flexion angle significantly decreased between asymptomatic and both OA groups (groups M, S), but there was no significant decrease between the moderate and severe groups. In our study, we found that the peak knee flexion angle was significantly different between the severe group and both the asymptomatic and moderate groups. In a study by Zeng et al. [21], the peak knee flexion angle progressively decreased with the advancement in disease. We found that the peak knee flexion had a good positive correlation with the KOOS and KSS knee scores. Similarly, in a study by Liebensteiner et al. [22], they found a good positive correlation between the peak knee flexion angle and KSS score.

Patients with KOA had a limited range of motion, mostly to alleviate pain, which was seen in our study, i.e., progressively decreased range of knee flexion angle between the asymptomatic and moderate to severe group, which was similar to a study by Zeng et al. [21]. However, a study by Astephen et al. [17] showed no significant difference in the knee flexion angle between asymptomatic and moderate, but there was a significant difference between the asymptomatic and severe groups.

The flexion angle at heel strike increased between asymptomatic and KOA patients, but it did not differ significantly between the asymptomatic, mild, and severe groups, whereas Zeng et al. [21] found heel strike increased with the advancement of the disease.

The peak knee flexion angle till mid-stance increased significantly between the severe group and both the asymptomatic and mild groups, but it did not increase significantly between the mild and asymptomatic groups. In the study by Astephen et al. [17], they found there is a significant increase in peak knee flexion angle till mid-stance with the progression of disease activity.

Our results showed that the adduction at heel strike increased significantly between the asymptomatic and both OA groups (moderate and severe groups) but did not differ significantly among moderate and severe groups. It differed from the study by Zeng et al. [21], where the adduction angle at the heel strike increased significantly among the severe group and both the asymptomatic and moderate groups, but it did not differ significantly between the asymptomatic and moderate groups.

In our study, the range of abduction/adduction decreases with the advancement of KOA, and it lowered significantly between the asymptomatic versus both OA groups (moderate and severe groups) but did not differ significantly among moderate and severe groups. The narrow joint space can limit the motion of the knee, thereby reducing the range of adduction/abduction. In the study by Zeng et al. [21], it decreased significantly between the asymptomatic and severe groups and not between the asymptomatic versus moderate or moderate versus severe groups.

In our study, the internal rotation at heel strike increased between the asymptomatic and severe groups but did not differ significantly among the 3 groups in our study. In the study by Zeng et al. [21], the internal rotation at heel strike increased significantly between the asymptomatic and severe groups which was due to increased rotational deformity of the knee.

In our study, the peak knee adduction moment did not differ significantly between the mild and severe groups. A similar result was found by Kean et al. [23] and Thorp et al. [18] but differed from the study conducted by Sharma et al. [24] and a study conducted by Naili et al. [25] where they found a significant increase in the peak knee adduction moment between the moderate and severe groups. The peak knee adduction moment increased significantly between the asymptomatic and severe groups as in the study by Thorp et al. [18].

In our study, the minimum adduction moment at mid-stance increased significantly between the asymptomatic and severe groups but not differed significantly between the mild and severe groups. It was similar to the study by Astephen et al. [17]. But unlike our study, the minimum adduction moment at mid-stance increased significantly between the asymptomatic and mild groups in the study by Astephen et al. [17].

In the study by Astephen et al. [17] the peak knee flexion moment decreased significantly between asymptomatic and both OA groups and did not decrease between the moderate and severe groups, and similar results were found in our study. The knee flexion moment decreased with increasing KOA severity which may be a compensatory mechanism of limiting knee flexion [26].

In our study, the peak knee extension moment at late stance decreased significantly between the asymptomatic and both OA groups, whereas in the study by Astephen et al. [17], it decreased significantly only between the asymptomatic and severe groups. Our result and the study by Astephen et al. [17] both showed that the peak knee extension moment at late stance did not differ significantly between the moderate and severe groups.

The peak knee internal rotation moment difference between the groups was not significant in our study, whereas there was a significant decrease between the asymptomatic and severe groups in the study by Astephen et al. [17].

Naili et al. [27] observed there was a significant decrease in GDI in OA knee patients compared to healthy control, which was similar to our study. In our study, we found that GDI decreased between the moderate and severe groups but was statistically not significant, whereas in the study by Naili et al. [25], they found that there was a significant decrease in GDI score between the mild and severe groups.

In our study, we found that the gait profile score had significantly increased with the advancement of knee osteoarthritis. No study in the literature made a similar conclusion. The gait profile score had a high negative correlation with KOOS and KSS knee scores in our study.

In our study, in KOA any severity (all OA) gait changes were observed in step length, percentage of stance phase, abduction/adduction angle at heel strike, ROM of knee abduction/adduction angle, peak knee flexion moment, knee adduction moment mid-stance minimum, knee flexion moment late stance minimum, and GDI. In knees with severe OA, the changes were seen in knee flexion angle peak till mid-stance, peak knee flexion angle, and progressive OA changes were observed in KSS knee score, knee flexion angle range, and gait profile score. In the study by Astephen et al., similar results were found in all OA and the gait changes were observed in knee adduction moment mid-stance minimum and peak knee flexion moment, and severe OA changes were observed in peak knee flexion angle. The difference in results was related to gait variables like percentage of the stance phase (progressive OA change in a study by Astephen et al. and all OA change in our study), knee flexion moment late stance minimum (only in severe OA group in the study by Astephen et al. and all OA change in our study), and knee flexion angle peak till mid-stance (progressive OA change in Astephen et al. and severe OA change in our study) [17].

The K/L score derived from radiography evaluated the osteophytes, joint spaces, and subchondral cysts, but it is not useful to determine the outcomes of conservative treatment. A combination of radiography and 3D gait analysis could guide us in the conservative management of patients with mild and moderate KOA without the necessity of arthroplasty.

Limitations and Strengths of the Study

In our study, we did not recruit age-matched controls, so there is a chance of confounding and bias associated with it. Along with this, the other limitation was that there are very few patients in the moderate group.

The strengths of this study include using a case mix of individuals with KL grades ranging from 1 to 4, and the use of several measurements of knee and gait function representing multiple constructs including functional scores, specific proxy measures of medial knee compartment loading, and measures of overall gait function derived from three-dimensional gait analysis.

Conclusion

KOA patients were significantly obese with slower walking speed, short stride length, longer stride time, and decreased cadence compared to the asymptomatic group. Various spatiotemporal, kinetic, and kinematic parameters like peak knee flexion angle, abduction/adduction angle, peak knee adduction moment, range of knee flexion, peak knee flexion, and GDI along with functional scores (KSS and KOOS) varied significantly with the progression of the disease.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s43465-024-01103-9.

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Data availability The datasets analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors of this paper have no conflicts of interest to declare in the preparation and submission of this manuscript.

Ethical Approval and Consent to Participate This study was conducted in AIIMS, New Delhi after getting approval from the Institute review board and ethics committee (IECPG-701/23.12.2020).

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