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Does total knee arthroplasty affect pelvic movements? A prospective comparative study

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SUMMARY

OBJECTIVE: Pathology in any segment of the spine-pelvis-lower extremity may impair the global postural balance, leading to compensatory alterations in other parts. The aim of this study was to compare the pelvic movements of patients suffering from knee osteoarthritis with patients who underwent total knee arthroplasty and healthy controls.

METHODS: This study was performed at the Department of Orthopedics and Traumatology Clinic of a Cankiri State Hospital between April 2021 and February 2022. This study included 84 participants. Of them, 31 patients who underwent total knee arthroplasty between 2018 and 2020 years were selected as the total knee arthroplasty group, while 28 patients with knee osteoarthritis were selected as the knee osteoarthritis group. In the control group, there were 25 healthy individuals. Exclusion criteria from the study included any kind of neurological disease, an inability to walk a distance of 100 m unassisted, or a history of surgery to the lower limb. Pelvic movements (i.e., tilt, rotation, and obliquity) and gait parameters (i.e., "gait velocity," "cadence," and "stride length") were assessed using a wireless tri-axial accelerometer.

RESULTS: Total knee arthroplasty and control groups had decreased minimum anterior tilt of the pelvis, decreased maximum anterior tilt, and decreased oblique range of the pelvis compared with the knee osteoarthritis group. In comparison with the control group, gait velocity and length of stride during gait were remarkably lower in both knee osteoarthritis and total knee arthroplasty groups.

CONCLUSION: In this study, total knee arthroplasty was found to affect pelvic movements. It was thought that total knee arthroplasty changed these variables, probably owing to the frontal and sagittal plane alignment correction through surgery.

KEYWORDS: Knee replacement arthroplasty. Knee osteoarthritis. Pelvic examinations.

INTRODUCTION

Knee osteoarthritis (KOA), which is a chronic and degenerative joint disease, leads to impaired mobility and pain, affecting a substantial number of individuals globally[1]. Total knee arthroplasty (TKA) is the gold standard that alleviates pain, improves functions, and restores tibiofemoral joint alignment in patients with KOA[2,3].

Biomechanically, the human body has a multi-segmental structure to execute main coactions between the adjacent segments. The interaction that happens between segments may be of utmost importance for asymptomatic musculoskeletal function. The primary role of the pelvis located in the body center is to connect the upper torso to the lower limbs[4]. Any segment of the spine-pelvis-lower extremity that has pathology may impair the global postural balance, leading to compensatory alterations in other parts of the body[5].

Severe KOA can dramatically influence the sagittal alignment of the spine-pelvis-lower extremity. To the best of our knowledge, few studies in the literature evaluated pelvic movements in patients with KOA undergoing TKA. This study aimed to compare the pelvic movements of patients suffering from KOA with patients who underwent TKA and age-matched healthy controls. In this study, we tested the hypothesis that patients suffering from KOA could walk with an anterior tilt of the pelvis, and following TKA, pelvic movements would be similar to those of healthy individuals.

METHODS

This single-centered and prospective study was performed at the Department of Orthopedics and Traumatology Clinic of a Cankırı State Hospital between April 2021 and February 2022. A total of 84 participants took part in this study. After

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the approval by the institutional Ethics Committee (Approval Date: 02.03.2021 and Approval Number: 2021-274), participants who underwent bilateral TKA due to osteoarthritis and had bilateral KOA, and age- and sex-matched asymptomatic healthy individuals were included.

A total of 31 patients who underwent bilateral TKA performed by an experienced orthopedic surgeon were selected as the TKA group. The patients were recruited if they underwent knee replacement 1 year, but no longer than 3 years prior to their inclusion. All TKA patients used posterior stabilized implants. A cemented total knee prosthesis (Tipmed, Turkey) was implanted using a standard medial parapatellar approach. Exclusion criteria were as follows: (1) spinal surgery pre- and post-TKA, (2) morphological changes in the vertebral body because of osteoporotic compression or traumatic fractures, (3) pain in low back and hip during walking, (4) history of a central nervous system illness, (5) severe heart or lung disease, (6) rheumatoid arthritis, and (7) inability to walk independently.

A total of 28 patients with KOA who required surgery were selected as the KOA group. All of the participants in the KOA group had bilateral KOA. The Kellgren-Lawrence (KL) radiographic grade from basic X-ray images was used to verify progression in patients with KOA. The KL grade was found to be III or IV in patients with KOA. An experienced orthopedic surgeon diagnosed all participants. In this study, the knee OA subjects had OA changes not only in the tibia but also in the femur, and only medial OA was examined.

The control group who had neither diseases nor gait disorders consisted of 25 age- and sex-matched healthy volunteers. Healthy participants were included in the study on the condition that they had not had any lower limb pain or back pain for the last 6 months.

Exclusion criteria from the study included any kind of neurological disease, cardiovascular disorder, an inability to walk a distance of 100 m unassisted, or a history of surgery to the lower limb.

Before the study, the researcher informed all participants about the nature of the study and obtained written informed consent from the participants. The study was carried out pursuant to the principles of the Declaration of Helsinki.

The demographic and epidemiological characteristics such as age, weight, height, and body mass index of all participants were registered.

Outcome measures

Pelvic movements

Pelvic movements (i.e., tilt, rotation, and obliquity) and gait parameters (i.e., gait velocity, cadence, and stride length) were measured, while participants walked freely along a 10 m walkway by using a wireless tri-axial accelerometer (G-Walk, BTS Bioengineering S.p.A., Italy) that was attached to the fifth lumbar vertebra and tightened with VelcroTM.

Gait velocity is the distance traveled by the body in a given time period. Stride length is the distance between the ground contact point of one heel and the ground contact point of the same heel. Cadence is the number of steps in a given time. It is usually calculated as the number of steps per minute. To assess the pelvic movement and gait parameters, the participants stood still in an orthostatic standing position, which continued for a few seconds until the stabilization of the G-Walk device ended. The participants received instructions on how to walk on a 10 m track, whose boundaries were labeled for an accurate analysis. The participants were allowed to walk with non-heeled casual shoes on firm surfaces. The participants kept a totally straight line while moving at their usual pace. They did a successful trial by completing the 10 m track and returning to the initial point[6,7].

The accelerometer data were wirelessly transferred by a Bluetooth system and analyzed with BTS G-studio software (BTS Bioengineering S.p.A., Italy) on a computer. The weight of the accelerometer was 37 g, with dimensions of 70×40×18 mm. The frequency of the accelerometer was from 4 to 1,000 Hz and sensor fusion was 200 Hz. The pelvic movement which has included all three planes was analyzed by using the BTS G-studio software program. G-walk is a reliable device for evaluating gait in healthy adults. The assessment of pelvic angles had moderate test–retest reliability (ICC: 0.463-0.659)[7,8].

Statistical analysis

In the *post-hoc* power analysis for the study, the effect size (f), calculated considering the pelvic movement values, was 0.446. When a total of 84 participants were involved, we calculated that the power of the study was 0.95 and α value of 0.05 (G*Power 3.0.10 system, Franz Faul, Universität Kiel, Germany)[9].

Statistical analysis was carried out by using the SPSS v. 22.0 software (IBM Corp., Armonk, NY, USA). The variables were assessed using analytical (i.e., Kolmogorov-Smirnov/Shapiro-Wilk test) and visual methods (i.e., histograms and probability plots) to ascertain whether or not normal distribution was ensured. Where applicable, descriptive statistics were provided as mean±standard deviation (SD), median (min-max), or number and frequency. As the demographic information and gait metrics were not normally distributed, the Kruskal-Wallis tests were used to compare these metrics between the groups. The Mann-Whitney U test was used to analyze the importance of pairwise differences by using the Bonferroni correction to measure multiple comparisons. As the pelvic movements were normally distributed, one-way analysis of variance was benefited in the comparison of these parameters between the groups. The homogeneity of the variances was tested by using the Levene test. Pairwise *post-hoc* tests were conducted using the Tamhane-T2 test in the case of an overall significance. A p-value of <0.05 was deemed statistically significant.

RESULTS

Characteristics of participants

Initially, 110 participants were identified from the recorded data. After applying the inclusion and exclusion criteria, 11 (10%) patients who underwent bilateral TKA and unable to walk independently, 9 (8.1%) patients with KOA who had a history of surgery to the lower limb, and 6 (5.4%) healthy participants who had any lower limb pain or back pain for the last 6 months were excluded. Thus, a total of 84 participants were eligible for this study. The attributes of the participants are shown in Table 1. The groups showed no significant differences in terms of age, body weight, or body mass index (p>0.05).

Pelvic movements

The maximum and minimum anterior tilts and obliquity range of motion (ROM) of the pelvis differed significantly by the groups. According to the pairwise comparison results, this difference was due to the KOA group.

Minimum and maximum anterior tilts and obliquity ROM of the pelvis were significantly larger in the KOA group than control (p=0.002, p<0.001, and p<0.001, respectively) and TKA (p=0.008, p<0.001, and p=0.006, respectively) groups.

The groups showed no significant differences regarding the rotation ROM (p>0.05). Pelvic angles for the TKA, KOA, and control groups are shown in Table 2.

Table 1. Demographic and epidemiological data for the total knee arthroplasty, knee osteoarthritis, and control groups.

Variable	TKA (n=31)		KOA (n=28)		Control (n=25)		p-value*
	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	
Age (years)	67 (50–76)	65.39 (6.76)	64 (54–75)	63.86 (6.71)	64 (53–73)	62.48 (5.36)	0.187
Height (cm)	158 (151–176)	159.97 (6.35)	165 (152–178)	163.43 (7.33)	175 (150–161)	162.36 (6.17)	0.129
Weight (kg)	88 (67–115)	88.11 (13.22)	87 (66–117)	89.60 (12.05)	83 (67–114)	85.65 (11.75)	0.465
BMI (kg/m^2)	35 (24–49)	34.69 (5.76)	33 (24–47)	33.79 (5.90)	31 (25–46)	32.54 (5.18)	0.326
Sex (male: female)	6:25		6:22		7:18		0.734

TKA: total knee arthroplasty; KOA: knee osteoarthritis; SD: standard deviation; BMI: body mass index. *Kruskal-Wallis test (p<0.05).

Table 2. Pelvic Angles for the total knee arthroplasty, knee osteoarthritis, and control groups.

Pelvic angles	TKA (n=31)		KOA (n=28)		CONTROL (n=25)		p-value*
	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	
Anterior tilt max (⁰)	13 (7–18)	12.09 (2.9)	15 (10–20)	15.1 (2.5)	11 (5–19)	11.5 (4.3)	**0.002*** KOA-Control **0.008*** KOA-TKA
Anterior tilt min (⁰)	8 (4–14)	8.2 (2.5)	11 (6–15)	10.9 (2.4)	7 (2–11)	6.7 (3.5)	**0.000*** KOA-Control **0.000*** KOA-TKA
Obliquity range of motion (⁰)	8 (3–10)	7.3 (1.4)	9 (5–12)	8.8 (2.0)	7 (3–11)	6.2 (2.0)	**0.000*** KOA-Control **0.006*** KOA-TKA
Rotation range of motion (⁰)	8 (5–11)	7.8 (1.6)	8 (3–11)	7.6 (1.7)	8 (4–14)	8.0 (2.0)	0.726

TKA: total knee arthroplasty; KOA: knee osteoarthritis; SD: standard deviation. *One-way ANOVA (p<0.05), post-hoc Tukey's test (p<0.017). Statistically significant p-values are given in bold.

Gait parameters

There were meaningful differences between the groups relating to gait velocity and stride length (p<0.05). According to the pairwise comparison results, the difference in speed and stride length was caused by the difference control group. When compared with the control group, gait velocity and stride length during walking were lower in both KOA and TKA groups at a significant level. There were no meaningful differences in cadence between the groups (p>0.05). The gait parameters for the TKA, KOA, and control groups are shown in Table 3.

DISCUSSION

In this study, patients with KOA had significantly larger anterior pelvic tilt than the asymptomatic controls. The anterior pelvic tilt decreased in patients with TKA compared with the KOA group, but not as much as the control group. This study has introduced outcomes supporting our theory that TKA could lead to changes in pelvic movements. To the best of our knowledge, this is the first study to evaluate pelvic movements (i.e., rotation, tilt, and obliquity) in patients following TKA.

A previous study asserted that, in the simulation of a 30° unilateral knee flexion contracture in healthy females by the use of a knee brace, an increase was observed in the anterior inclination of the pelvis and trunk in the course of walking; however, this was not detected at a 15° of contracture in knee flexion[10]. It is possible that the patients who had severe KOA were susceptible to anterior pelvic tilt, as seen in the participants of this study. Kuwahara et al.[11], similar to our study, reported that patients with KOA could walk along with larger anterior tilts of the pelvis and trunk prior to the operation when compared with controls. However, after 1 year of surgery, no significant differences in the anterior tilt of the pelvis were observed between pre- and post-TKA in the KOA patients. All body joints are functionally structured with the purpose of minimizing energy use depending on the gravity line in the capacity of being a center during standing[12]. Murata et al.[13] showed significantly reduced lumbar lordosis in patients whose knee extension limitation was found to be over 5°, and gonarthrosis could indirectly lead to lumbar spine-related symptoms. The authors defined this fact as "knee-spine syndrome." In our study, the limited knee joint extension patients with KOA gave rise to a posterior displacement in the center of gravity, suggesting that an induced anterior pelvic tilt might be a compensatory approach. As the extension limitation disappeared after TKA, the anterior pelvic tilt may have decreased.

Although frontal plane kinematics has been discussed in limited research, evidence suggests that TKA changes these variables, probably because of frontal plane alignment correction through the operation. The main goal of TKA is to enhance the tibiofemoral loading environment, specifically by decreasing malalignment in the frontal plane which usually occurs with KOA[14]. The existence of extreme varus-valgus movement in patients with KOA may have caused abnormal knee joint loading, leading to increased oblique movements of the pelvis[14]. This study indicates that the obliquity ROM of the pelvis was significantly larger in the KOA group, although this obliquity was decreased after TKA.

There are several studies showing that 1 year following TKA knee kinematics is still different in comparison with healthy joints. In general, compared with the control individuals, the knee flexion range in patients with TKA is smaller and extension of the knee during walking is decreased, and stride length and cadence are reduced[15,16]. Although our main objective in our study was to evaluate the pelvic movements, we also examined the walking speed of the participants

Table 3. Gait parameters for the total knee arthroplasty, knee osteoarthritis, and control groups.

Gait parameters	TKA (n=31)		KOA (n=28)		Control (n=25)		p-value*
	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	
Gait velocity (m/s)	0.93 (0.55–1.30)	0.91 (0.19)	0.93 (0.64–1.14)	0.90 (0.14)	1.07 (0.61–1.48)	1.05 (0.23)	**0.005*** KOA-Control **0.014*** TKA-Control
Cadence (steps/min)	102 (79–126)	103.86 (10.25)	106 (87–125)	105.25 (9.32)	107.04 (91–135)	109.93 (10.10)	0.070
Stride length (m)	1.04 (0.78–1.43)	1.06 (0.16)	1.03 (0.71–1.42)	1.03 (0.15)	1.21 (0.77–1.56)	1.17 (0.22)	**0.007*** KOA-Control **0.016*** TKA-Control

TKA: total knee arthroplasty; KOA: knee osteoarthritis; SD: standard deviation. *Kruskal-Wallis test (p<0.05), Mann-Whitney U test with Bonferroni correction (p<0.017). Statistically significant p-values are given in bold.

due to the relationship between pelvic movements and gait speed. A previous study showed that the ROM of the pelvis and lumbar region during gait was greater at high velocity than at the preferred velocity[17]. Nonetheless, there was no significant change in the walking speed of the KOA and TKA groups; therefore, it was unlikely for speed to be a confusing variable in this study. Moreover, even after TKA an average of 1.9 years, the stride length and walking speed were significantly lower than the control group. This may be the result of patients still having differences in knee kinematics 1.9 years after surgery and ongoing pain symptoms. We believe that improved comprehension of both deteriorations and functional limitations after operation may be helpful for clinicians to tailor rehabilitation programs. Also, rehabilitation following TKA takes a long time, which should be reminded to the patients.

Nonetheless, there are some limitations to this study. First, ROMs were not measured during the study. Second, because there was neither pain nor deformity in the control subjects' knee joint in the process of gait, the presence of radiological knee OA was unable to be confirmed. Depending on the ages of the controls, there might be inconsiderable degeneration in their knee joints. However, we employed them in the control group because they nearly had a normal knee function.

In spite of the limitations of this study, as far as we know, not many studies have discussed the movements of pelvic on a large population suffering from severe KOA and following TKA, which is the main strength of this study.

CONCLUSION

In conclusion, patients with severe KOA showed a more anterior pelvic tilt compared with asymptomatic controls. In patients with TKA, the anterior pelvic tilt decreased, but not as much as in the control group. Furthermore, the KOA group had significantly greater obliquity ROM of the pelvis; however, following TKA, this obliquity was decreased. Further studies may focus on changes in sagittal alignment and low back pain in individuals with KOA before and after TKA.

AUTHORS' CONTRIBUTIONS

EAP: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **YP**: Conceptualization, Formal Analysis, Investigation. **GMK**: Formal Analysis, Investigation, Writing – review & editing. **ME**: Formal Analysis, Investigation, Writing – review & editing. **NK**: Methodology, Supervision, Writing – review & editing. **NAG**: Conceptualization, Methodology, Supervision.

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